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EXPERIMENTAL INSTALLATION OF MAST MOUNTED SIGHT ON AN OH-58C HE--ETC(U)
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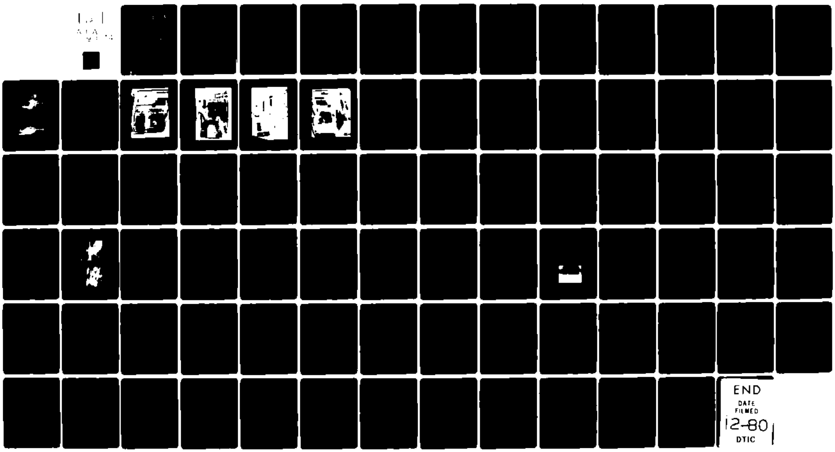

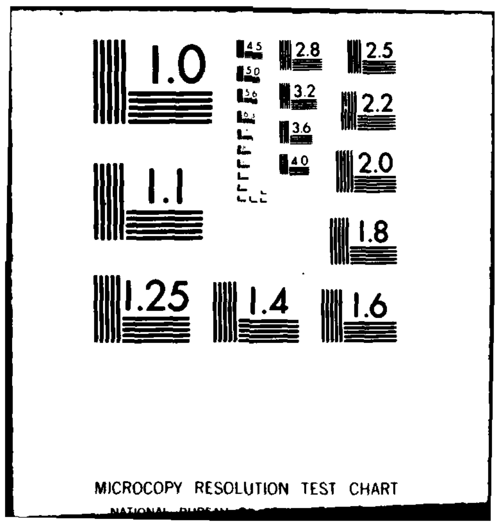
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EXPERIMENTAL INSTALLATION OF MAST MOUNTED SIGHT ON AN OH-58C HELICOPTER

James A. Rule, Horace W. Hanson, Harry K. Harr, John P. Norvell, David A. Popelka

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Final Report for Period March 1978 - January 1980

Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

The Mast Mounted Sight (MMS) concept shows promise of permitting a scout helicopter to detect and designate targets for precision guided weapons while operating behind masking features, thus reducing the detectability of the helicopter by visual, infrared, and radar guided antiaircraft threat systems.

The presence of the MMS affects helicopter dynamics, handling qualities, and loads, while the vibrational environment of the rotor mast affects the performance and life of the MMS.

A dynamic environment analysis indicated that severe penalties in MMS performance and component life, and a greatly restricted helicopter flight envelope, would result from a hard-mounted installation on the OH-58C. Use of a Bell Helicopter-designed focal mount reduced translational accelerations of the MMS center of gravity from above 6 g's to about 2 g's, well within the design envelope of the Rockwell International MMS.

A carefully selected combination of main rotor mast, trunion, and split-cone set, resulting to minimal eccentricity with respect to the mast axis of rotation, was required to obtain acceptable one-per-rev vibration levels at both the MMS and the crew stations simultaneously.

Results demonstrated the feasibility of installing a MMS on the OH-58C, with minimal effect on either the performance or handling qualities of the helicopter.

Mr. Kenneth D. Hampton of the Aeronautical Systems Division served as project engineer for this effort.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this effort was to investigate the load and vibration effects of installing a Rockwell mast mounted sight (MMS) on an OH-58C helicopter and to determine the environment in which the sight would operate. The task consisted of analytical studies, tests with a dummy sight, and installation and test of an operational sight.

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PREFACE

This report contains the results of a feasibility demonstration program to install and test a Rockwell mast mounted sight system on an OH-58C helicopter. The effort consisted of analytical studies; design, fabrication, and test of an instrumented dummy sight; and installation and test of the actual sight. This program was conducted by Bell Helicopter Textron (BHT) for the U.S. Army Research and Development Command (ARRADCOM) from March 1978 to February 1979 and for the Applied Technology Laboratory (ATL), U.S. Army Research and Technology Laboratories (AVRADCOM) from July 1979 to January 1980. Contract DAAK10-78-C-0115 funded the total effort.

The ARRADCOM technical direction was provided by Kennard W. Raisner and ATL technical direction was provided by Kenneth D. Hampton. This program was conducted under the technical direction of James A. Rule, Project Engineer, Bell Helicopter Textron.

TABLE OF CONTENTS

TABLE OF CONTENTS - CONCLUDED

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS - CONTINUED

LIST OF ILLUSTRATIONS - CONCLUDED

LIST OF TABLES

INTRODUCTION

Military tactics for scout helicopter missions require the helicopter crew to detect, identify, and laser-designate targets while minimizing exposure of the helicopter to enemy detection and attack. A mast mounted sight (MMS) and laser designator/range finder, located as high as possible above the helicopter rotor, allows the helicopter to take maximum advantage of terrain features with only the sight exposed to the enemy.

Installation of an MMS on a helicopter affects helicopter dynamics, structural loads, aerodynamic drag and handling qualities. The severe vibration environment found on top of a helicopter mast which the MMS must tolerate affects the accuracy of the sight and the life of the sight components.

To provide an insight into the effects of installing an MMS on a helicopter, two Army-sponsored studies were conducted by BHT. The first study (Reference 1) investigated the effects of sight weight and height above the rotor on a Model OH-58C helicopter. The second study (Reference 2) examined the feasibility of installing a TOW missile sight on the mast of an AH-1S helicopter using a nonrotating platform and standpipe which were developed for the SATCOM antenna.

Since the OH-58C study indicated that a reasonably sized MMS could be installed, Contract DAAK10-78-C-0115 was awarded to BHT for the experimental installation of a Rockwell sight on an OH-58C to demonstrate the feasibility of this system.

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[1]Rule, J. A., et al, "OH-58C Mast-Mounted Visionics Analysis," Bell Helicopter Textron Report Number 699-099-060, Fort Worth, Texas, July 1977.

[2]Rule, J. A., et al, "AH-1S Mast-Mounted TOW Sight Analysis," Bell Helicopter Textron Report Number 699-099-088, Fort Worth, Texas, July 1978.

TEST EQUIPMENT

TEST AIRCRAFT

The helicopter, shown in Figure 1, was a bailed U.S. Army OH-58C, Army Serial No. 69-16214. The dummy sight is shown installed on a focal mount on top of the mast. A BHT commercial Model 206 SCAS kit and hydraulically boosted tail rotor controls were installed in the helicopter to improve handling qualities and provide a stable platform for sight operation. The airframe was strengthened and a stiffer main rotor pylon isolation mount was installed.

Other modifications made to the helicopter to install the MMS included the following items:

> A standpipe with a splined fitting on each end was installed inside the main rotor mast supported by a mating splined fitting bolted to the bottom of the transmission and two bearings near the upper end of the mast.
>
> A splined nonrotating plate was installed in the upper end of the mast on the standpipe spline to support the MMS focal mount.
>
> The focal mount was installed between the nonrotating plate and the MMS.
>
> The cable assembly from the MMS was routed through the standpipe, out the bottom of the transmission, and through a hole in the cabin roof to the electronics equipment in the cabin.

DUMMY SIGHT INSTALLATION

The test equipment consisted of a bailed OH-58C helicopter, an instrumented dummy mast mounted sight which simulated the weight and shape of the Rockwell sight, a focal mount, instrumented main and tail rotor blades, instrumented controls, a slip ring assembly, numerous transducers, a telemetry multiplex package, a 13-channel telemetry transmitter and a helicopter-installed magnetic tape recorder with 104-channel capacity. The instrumentation package was installed on a rack in the aft passenger seat. A detailed list of the instrumentation used in flight tests with the dummy sight is included in the flight test reports.

ROCKWELL SIGHT INSTALLATION

Figure 2 shows the OH-58C with the Rockwell mast mounted sight installed on the focal mount. In addition to the sight, the Rockwell system included a number of electronic boxes and instrumentation equipment.

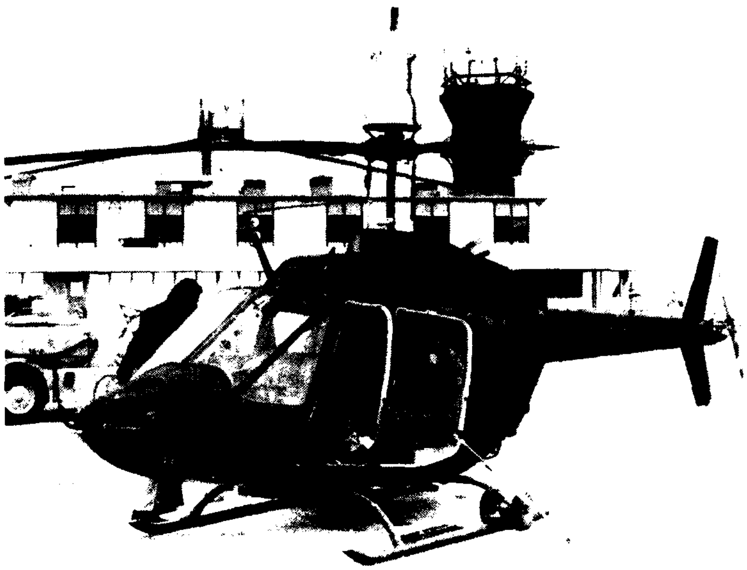

Figure 1. OH-58C with dummy sight installed.

Figure 2. OH-58C with Rockwell sight installed.

The BHT instrumentation rack and nearly all BHT instrumentation were removed to allow installation of the Rockwell system. Figures 3 and 4 show the Rockwell electronics and instrumentation installed in the rear seat and electronics compartment.

The observer's monitor was a pantograph-supported TV monitor, with sight and monitor controls located on modified hand grips on either side of the display. The copilot's cyclic and pedal controls were removed to make room for the display.

A small TV monitor was mounted on the right-hand side of the instrument panel to enable the pilot to maintain the correct altitude by positioning the MMS line of sight just above a protective hill or tree line. Figure 5 shows the observer's and pilot's monitors in the cabin. A third monitor and a video recorder were installed in the back seat for these tests as shown in Figure 6.

Instrumentation installed with the Rockwell sight consisted of the video recorder in the back seat and magnetic tape recorder installed in the electronics compartment. Accelerometers were installed in the sight by Rockwell. BHT installed accelerometers under the pilot's and observer's seats, and position potentiometers were installed on the focal mount. Table 1 lists the instrumentation transducers which were monitored during flight tests with the Rockwell sight.

TABLE 1. INSTRUMENTATION MONITORED DURING FLIGHT TESTS WITH ROCKWELL SIGHT

Descriptions	Units
MMS Azimuth Stabilization	Rad
MMS Elevation Stabilization	Rad
MMS Line-of-Sight Angular Acceleration	Rad/Sec^2
MMS C.G. Lateral Acceleration	G's
MMS C.G. F/A Acceleration	G's
MMS C.G. Vertical Acceleration	G's
Pilot Seat Vertical Acceleration	G's
Pilot Seat Lateral Acceleration	G's
Pilot Seat F/A Acceleration	G's
Copilot Seat Vertical Acceleration	G's
Copilot Seat Lateral Acceleration	G's
Copilot Seat F/A Acceleration	G's

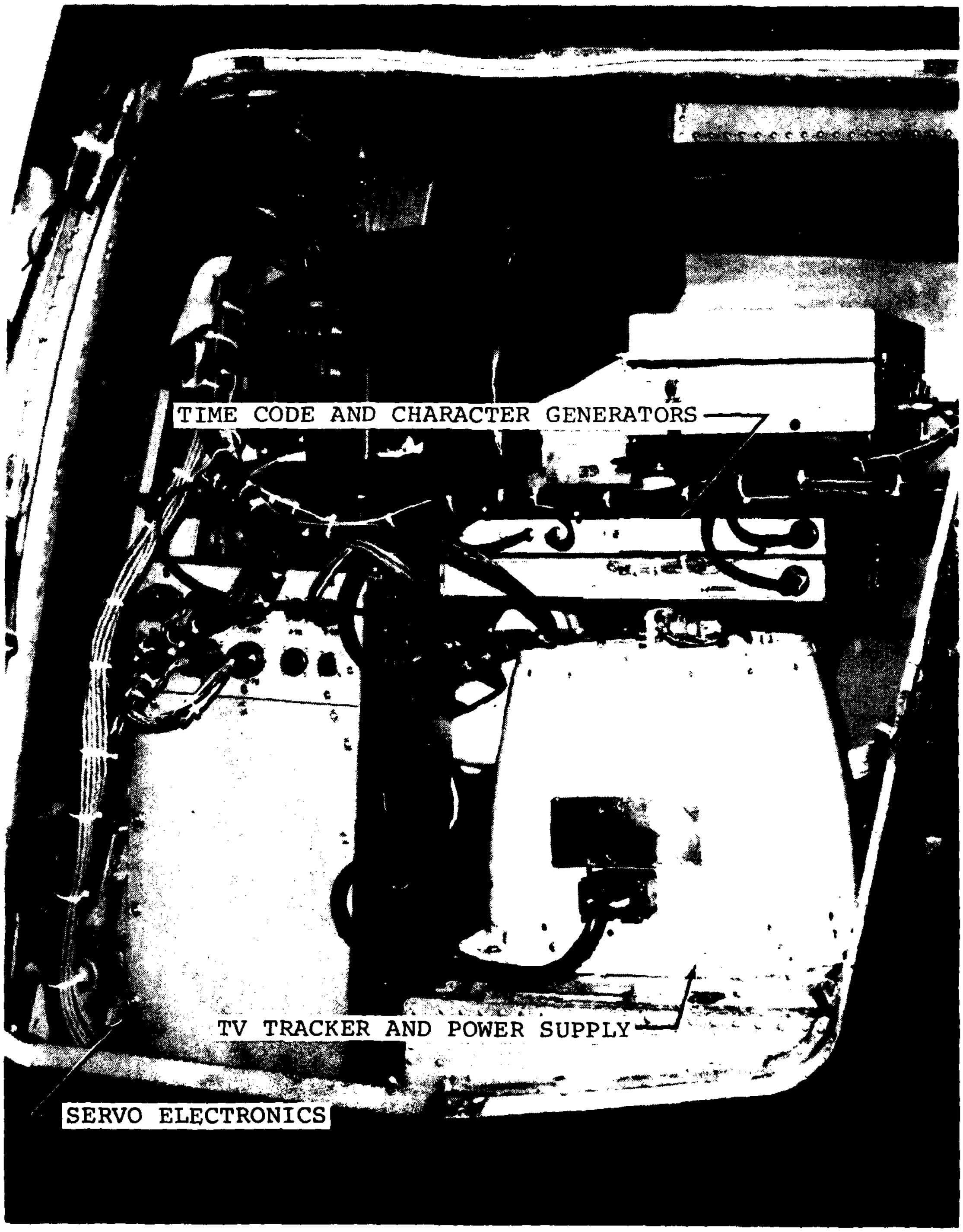

Figure 3. Rockwell MMS equipment installed in aft passenger compartment.

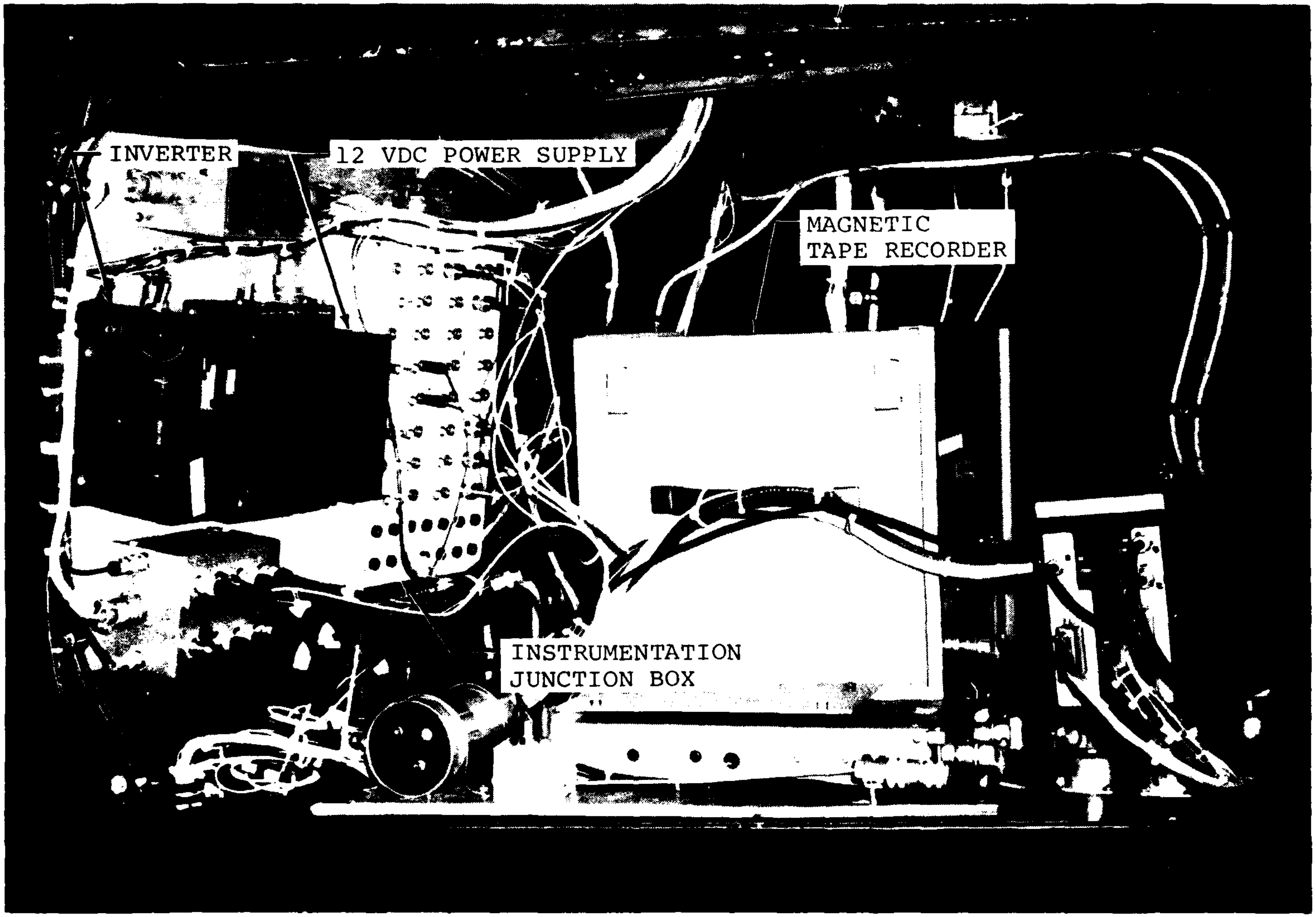

Figure 4. Rockwell equipment installed in avionics compartment.

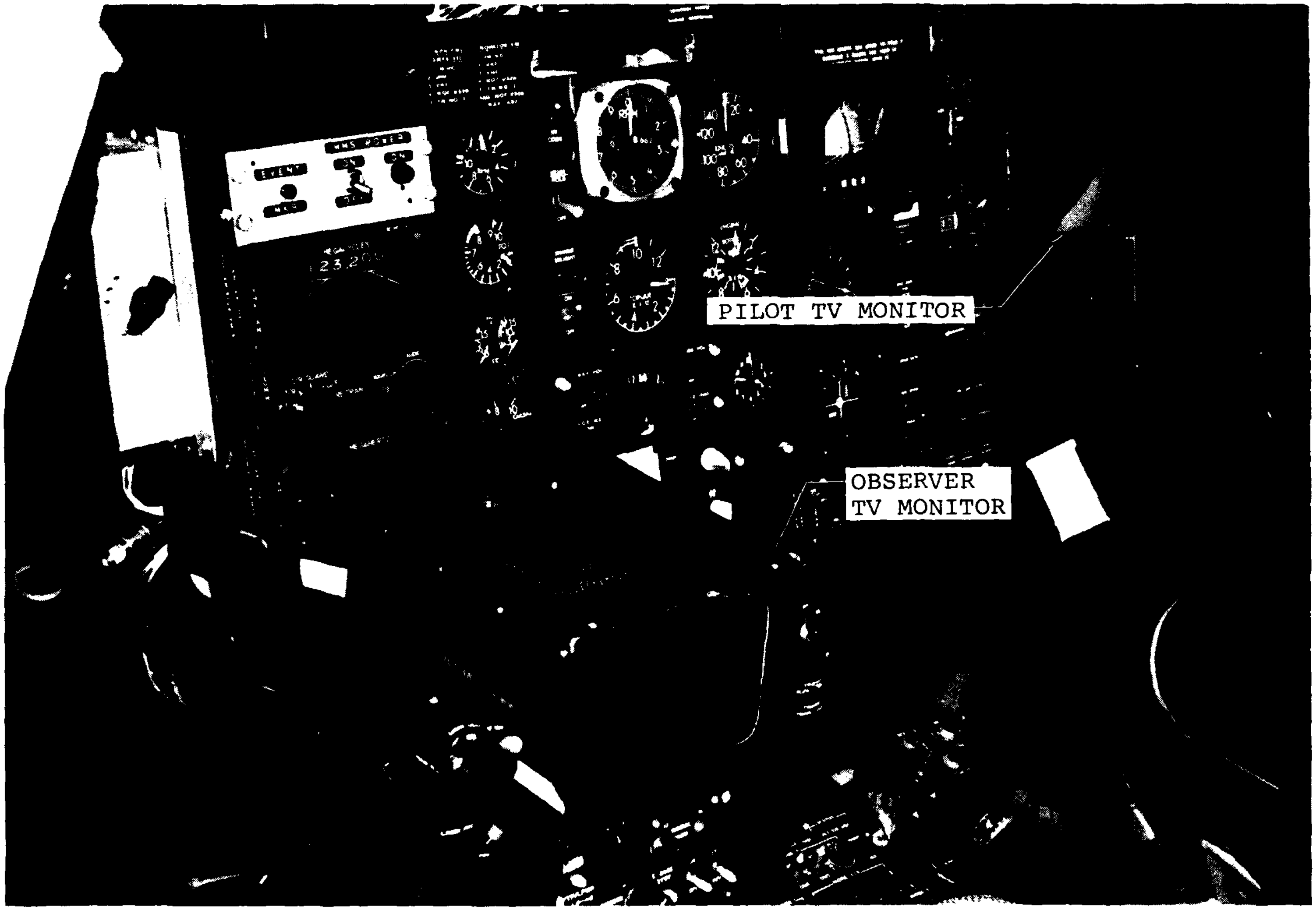

Figure 5. Observer's and pilot's TV monitors in OH-58C.

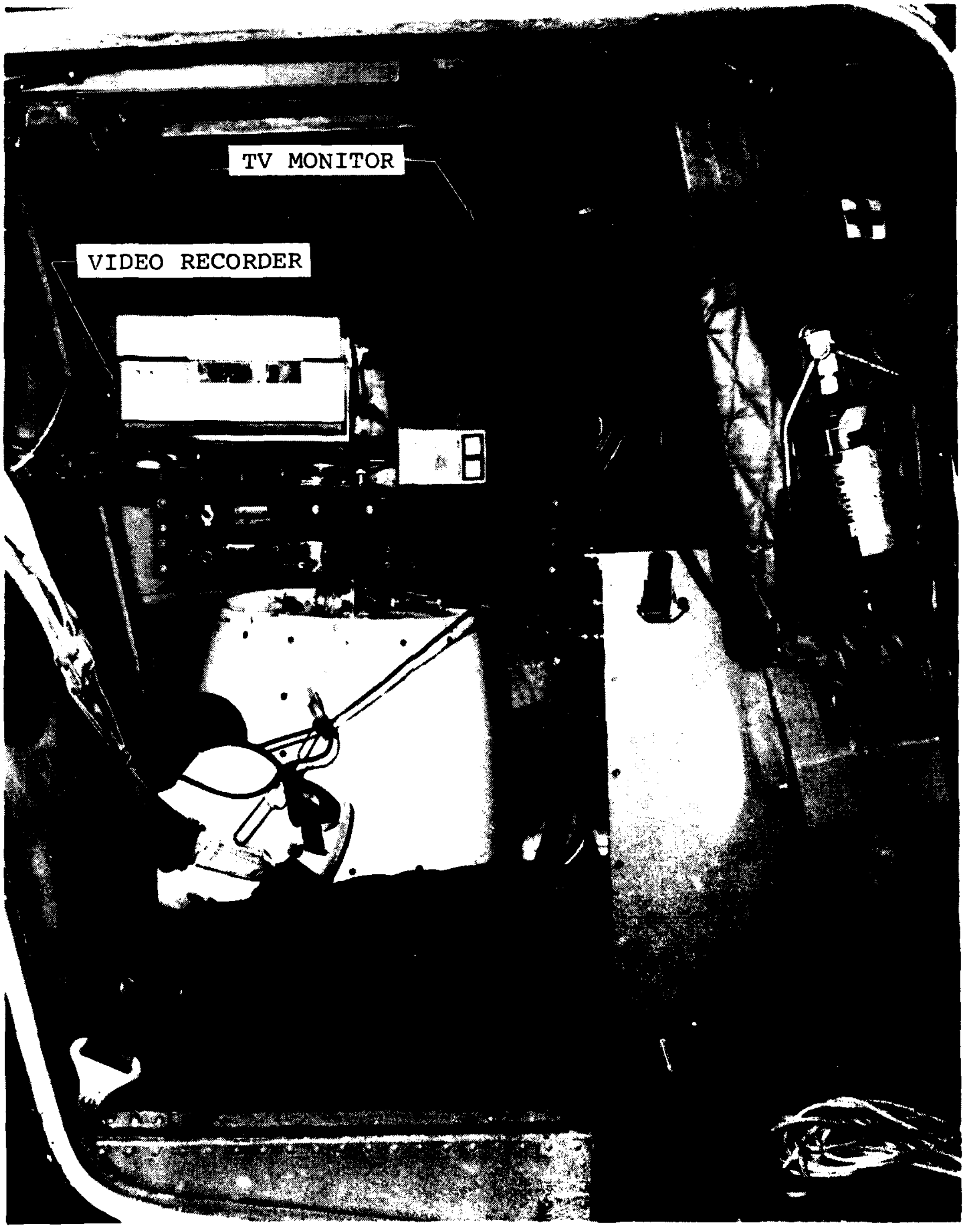

Figure 6. Passenger's TV monitor and video recorder.

DUMMY MAST MOUNTED SIGHT CONFIGURATION

GENERAL

The ground vibration test and most of the flight testing at BHT Flight Research Center at Arlington, Texas, were conducted with a dummy sight installed in lieu of the Rockwell sight. The primary reasons for using the dummy sight were as follows:

1. The Rockwell sight was not available during the test program time frame.

2. The dummy sight incorporated a slip ring which transferred electrical signals from the instrumented main rotor blade and rotating controls to the non-rotating airframe.

3. Instrumentation could be more easily added or changed in the dummy sight than in the Rockwell sight.

The dummy sight was designed to duplicate the weight, inertia, and general size and shape of the Rockwell sight. Because of the slip ring requirement, the outer shell of the dummy sight rotated with the rotor, whereas the Rockwell sight does not. The flat lens of the Rockwell sight was not duplicated on the dummy sight because of this rotation.

Feasibility studies, including dynamic and structural analyses using computer models, were conducted prior to the start of testing. Following the studies the helicopter was subjected to a series of ground shake tests with and without the dummy sight installed. Flight tests were then conducted using the dummy sight. Results of these analyses and tests are presented in the following sections.

FEASIBILITY STUDIES

Prior to the beginning of the mast mounted sight test program, dynamic and structural analyses were made to study the feasibility of installing the Rockwell sight on the OH-58C mast. The original plan was to hard mount the sight on a nonrotating platform located approximately 20 inches above the main rotor blade flapping axis.

Dynamic Analysis

A dynamic analysis of this configuration was conducted by BHT to determine the sight dynamic environment and the dynamic effects on helicopter components (Reference 3, Volume 1).

This analysis showed that a hard-mounted mast mounted sight on the OH-58C would reduce the main rotor hub mobility due to the inertia added to the hub and thereby greatly increase main rotor blade loads, especially during gusts and maneuvers.

As a result of this analysis, BHT funded the design and fabrication of a focal mount for the MMS, for which a patent has been applied. This mount utilized the same principle as the focal-mounted pylon system on the OH-58C. The MMS focal mount system reduced the translational and rotational vibration levels at the sight. In addition, it accomplished its main purpose of isolating the MMS from the main rotor hub. Volume 2 of Reference 3 describes the MMS focal mount system.

Supplementing the design of the MMS focal mount, the dynamic analysis was repeated with the MMS installed on the focal mount. This analysis is presented in Reference 4.

Structural Analysis

A structural analysis, Reference 5, was conducted to determine if the fuselage, transmission, mast and other helicopter components were suitable to support the weight of a mast mounted sight during normal operation and under crash load conditions.

As a result of this analysis, the fuselage roof, transmission mounting bolts, and drag pin were strengthened for the increased loads. The forward crash load factor on the mast was reduced from 16g's to 11.2g's with the dummy mast mounted sight installed on the focal mount (124.4 pounds at W.L. 137.2 inches).

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[3] Anderson, H., and Andrews, J., "Dynamic Environment Analysis of OH-58C Helicopter with Mast Mounted Sight Installed," Volumes 1 and 2, Bell Helicopter Textron Report No. 206-099-353, September 1978.

[4] Anderson, H., and Andrews, J., "Dynamic Environment Analysis of OH-58C with Focal Mounted Sight Installed," Bell Helicopter Textron Report Number 206-099-812, November 1978.

[5] Freeman, F., Hunt, G., Messick, J., Midgley, R., Rost, F., Roessler, D., "Structural Analysis of Mast Mounted Sight on the OH-58C Helicopter," Bell Helicopter Textron Report Number 206-099-354, Revision A, November 1978.

GROUND VIBRATION TEST

A ground vibration test of both the baseline OH-58C and the OH-58C with a dummy MMS installed was performed during October through December, 1978. The weight of the dummy sight used in the shake test was 69 pounds. The test plans and test results are reported in Reference 6. A hub mobility and natural frequency comparison of analysis and shake test results for both helicopter configurations is shown in Table 2.

The primary purpose of the ground vibration test was to evaluate the MMS focal mount system to determine the proper focal point location and spring rate combination required to provide optimal MMS two-per-rev vibration isolation. During the investigation of various MMS focal point and mount spring rate combinations, it was found that the flexibility of the MMS focal mount plates was degrading the performance of the focal mount system, resulting in larger MMS two-per-rev pitching motions than were predicted (see Figure 7 in Development Flight Test Section). For shake test evaluation, the upper focal plate was stiffened by installing struts from the four corners of the plate up to the dummy sight vertical support at approximately 45-degree angles. The lower focal plate was artificially stiffened by installing braces from the four corners of the plate down to the main rotor hub nut adapter (rotating system). With the stiffened focal plates, the MMS focal mount system was found to perform as the analysis had predicted, and the optimum MMS focal mount system parameters were determined, as are presented in Table 3. It was concluded that stiffer focal mount plates would significantly reduce the MMS two-per-rev pitching and rolling motions.

The MMS nonrotating static standpipe, which is installed inside the main rotor mast, was instrumented to detect contact between the standpipe O.D. and the mast I.D. No contact between these two shafts occurred during any of the ground vibration testing.

GROUND RUN

The first ground run with the dummy MMS installed was accomplished on 22 December 1978. The aircraft was secured to the ground during all ground runs. Cyclic and pedal reversals with varying main rotor rpm were accomplished with no adverse effects. On 3 January 1979 the OH-58C was ground run to check torsional stability. Cyclic, collective, and pedal inputs

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[6] Andrews, J., and Hanson, H., "Ground Vibration Test of the OH-58C with Mast Mounted Sight," Part I - Test Plan, Part II - Test Results, Bell Helicopter Textron Report Number 206-099-808, Revision C, March 1980.

TABLE 2. COMPARISON OF ANALYTICAL AND SHAKE TEST RESULTS

	Baseline OH-58C*		OH-58C With Mast Mounted Dummy Sight†	
	Analysis	Test	Analysis	Test
Focal Mount Spring Rate (lb/in.)	-	-	345.	460.
Two-Per-Rev Hub Mobility (in./lb-sec^2)				
Fore/Aft	1.33	1.25	1.32	1.19
Lateral	1.17	1.11	1.23	1.22
Natural Frequency (Hz)				
Fore/Aft M/R Pylon Rocking	3.35	3.73	2.48	<3.0
Lateral M/R Pylon Rocking	3.17	4.60	2.84	<3.0
Fore/Aft Sight Rocking	-	-	6.62	7.27
Lateral Sight Rocking	-	-	7.14	7.38
Lateral M/R Mast Bending	21.3	24.9	18.5	20.5
Fore/Aft M/R Mast Bending	71.2	72.2	30.2	24.2

*With 206-840-005-105 Mast Mounted Sight Support Assembly
†With 206-812-011 Focal Mounted Dummy Sight Installation

were made at increments of 10 percent M/R torque up to takeoff power. Rotor response and damping were normal. A subsequent ground run was done for EMC tests on the SCAS. No abnormalities were noted.

TABLE 3. MMS FOCAL MOUNT OPTIMIZED PARAMETERS

MMS Pitch:		
	Focal Point	W.L. 74
	Mount Spring Rate	350 lb/in.
MMS Roll:		
	Focal Point	∞
	Mount Spring Rate	350 lb/in.

DEVELOPMENT FLIGHT TEST

Initial development flight tests were conducted during January and February 1979. During this period several problems were encountered relative to the MMS focal mount system installation, the most important of which are summarized in Table 4 and discussed in the following paragraphs.

The first flight with the dummy sight installed on the OH-58C was accomplished on 9 January 1979. The helicopter was configured at a mid-center of gravity (cg) and 3100 pounds gross weight (GW). The weight of the dummy sight used during these tests was 72 pounds. The A/C was hovered and inputs were made with the cyclic stick and pedals. A high lateral main rotor one-per-rev vibration was evident. The pilot commented that the aircraft responded and handled very much like a standard OH-58C although it appeared to be somewhat more sluggish in a hover with SCAS off, i.e., required more pilot effort to stabilize in a hover. SCAS, when engaged, was a positive aid to the pilot in the hover mode.

The next several days were spent attempting to balance the main rotor. On 16 January 1979 with the main rotor still out of balance, a level flight sweep to 90 KIAS was made. Left and right turns, cyclic pedal and collective inputs were accomplished at several airspeeds. Flight test data verified the MMS focal plate flexibility which was detected during the ground vibration test. As shown in Figure 7, this additional flexibility in the MMS focal mount system resulted in raising the optimal focal point, thereby increasing the sight two-per-rev rotational response.

TABLE 4. DEVELOPMENT FLIGHT TEST PROBLEMS ENCOUNTERED

Problem	Cause	Action	Result
-MMS Mount Stop Contact	-Stops designed to account for drag of Rockwell MMS -With rotating cover and slip ring installed, dummy MMS is not exposed to drag	-Recontoured existing stops	-Stops still contacted during high g maneuver conditions due to excessive MMS cg one-per-rev translations and two-per-rev rotations
-MMS Slip Ring Drive Interference	-Instrumentation mechanical interference	-Added additional clearance	-Eliminated interference
-Main Rotor Pylon Gust Response Sensitivity	-Main rotor pylon natural frequency lowered by MMS installation	-Installed stiffer main rotor pylon mount	-Reduced main rotor pylon gust response -Increased two-per-rev airframe vibration

TABLE 4. - CONCLUDED

Problem	Cause	Action	Result
-Excessive MMS two-per-rev Rotations	-Upper/lower focal plate flexibility	-Recommended design and fabrication of stiffer focal plates	
-One-per-rev Response Anomaly	-Upper/lower focal plate flexibility	-If main rotor balanced for minimum MMS one-per-rev response, then pilot's seat one-per-rev vibration unacceptable	
	-Possible MMS natural frequencies near one-per-rev	-If main rotor balanced for minimum pilot's seat one-per-rev vibration, then MMS one-per-rev response unacceptable	
	-Possible misalignment of MMS hardware with mast axis of rotation	-Marginally acceptable one-per-rev response at both locations achieved by a compromise main rotor balance configuration	

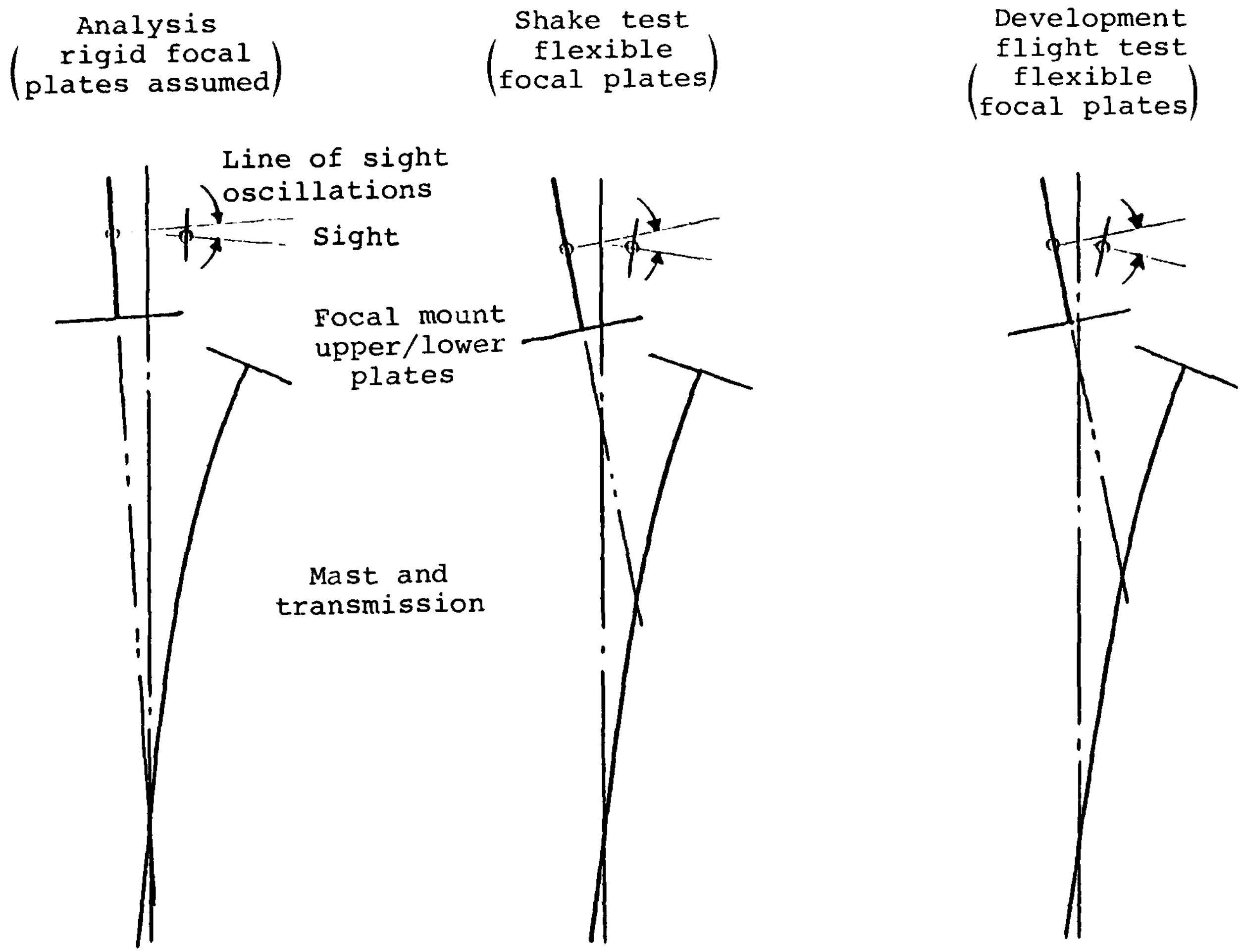


Figure 7. Comparison of MMS focal mount 2/rev pitch response deflection shapes.

On 19 January 1979, the main rotor was balanced so that the pilot's seat one-per-rev vibration level was reduced to 0.15 inch-per-second (IPS) during a hover. The aircraft was then flown for a level flight sweep to record sight vibrations. Approaching 85 KIAS the dummy MMS made contact with the focal mount stops, resulting in a main rotor pylon rocking mode motion evident in the cockpit. The flight was aborted.

It was noted that balancing the main rotor for minimum pilot's seat vibration resulted in a higher sight vibration level in hover and forward flight; conversely, with the main rotor balanced for minimum sight vibration, the pilot's seat vibrations were increased. The focal mount stops were opened up by 0.1 inch. On the next flight, while taxiing IGE, the focal mount stops were again contacted and the aircraft experienced pylon rock. It was noted that the abnormally high one-per-rev vibration used up a significant portion of the stop clearance. Again the focal mount stops were opened up another 0.1 inch (total of 0.2 inch), and the main rotor pylon mount stiffness was increased to reduce the pylon gust response sensitivity.

The one-per-rev vibration anomaly was further investigated by evaluating various MMS weight configurations at several helicopter center-of-gravity and gross weight conditions. It was found that practical sight weight variations had no appreciable effect on the one-per-rev problem, perhaps due in part to the flexibility of the MMS focal plates, but that sight two-per-rev vibrations were less with decreased sight weight (effectively the same as increasing the spring rate of the MMS mounts). For a 50-pound MMS weight configuration it was possible to obtain 110 KIAS in a dive prior to slight stop contact. In maneuvering flight at 85 to 90 KIAS and 1.3 to 1.4g's, slight stop contact was encountered.

For a 72-pound MMS configuration and a compromise main rotor balance providing marginally acceptable pilot's seat one-per-rev vibration, representative level flight vibration data for the MMS cg and the pilot's seat are shown in Figures 8 and 9, respectively. MMS translational response did not exceed 1.85g's, including maneuver and moderate gust conditions; pitch rotational response did reach the Rockwell limit during severe gusts at 85 KCAS. With the MMS installed, maximum continuous torque at level flight resulted in 96 KCAS, and V_{cruise} was estimated 86 KCAS. Pilot's seat one-per-rev vibration levels were significantly higher than on the baseline OH-58C aircraft, especially during hover and at the higher airspeeds. No adverse loads or handling qualities problems were encountered.

At this time the decision was made to suspend further testing until stiffer MMS focal plates were fabricated and installed on the helicopter.

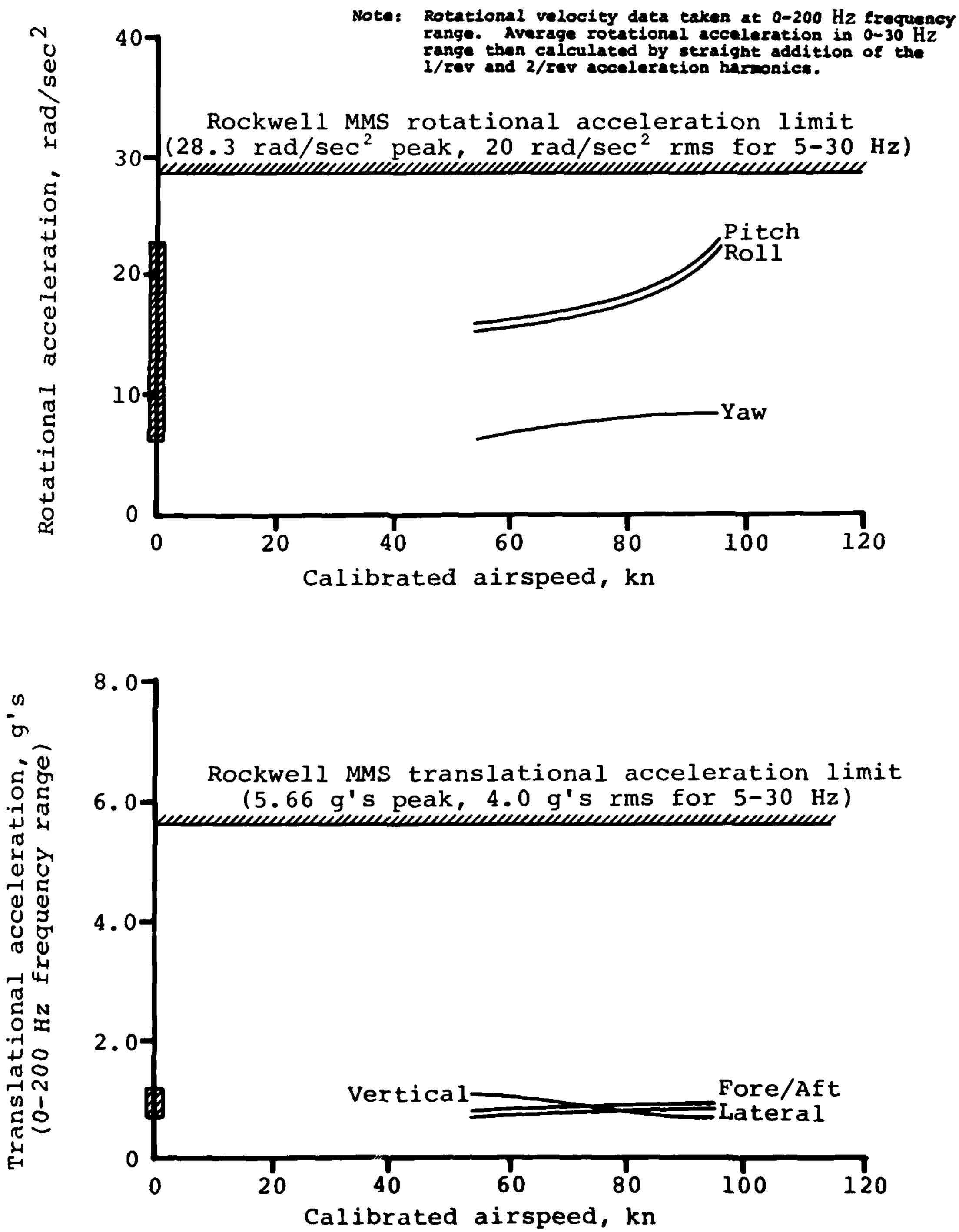
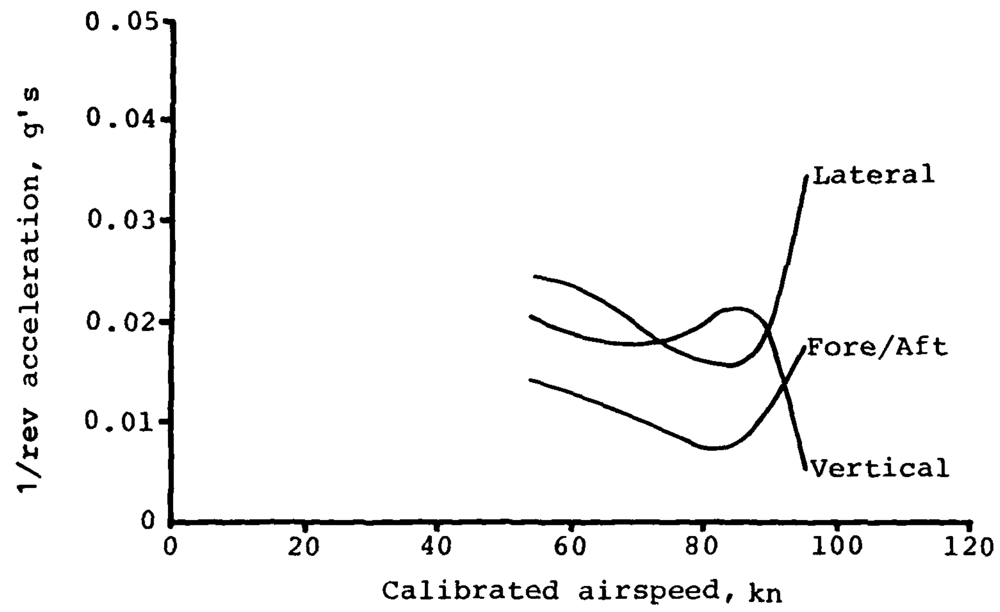


Figure 8. Dummy MMS cg average vibration versus level flight airspeed - development flight test.



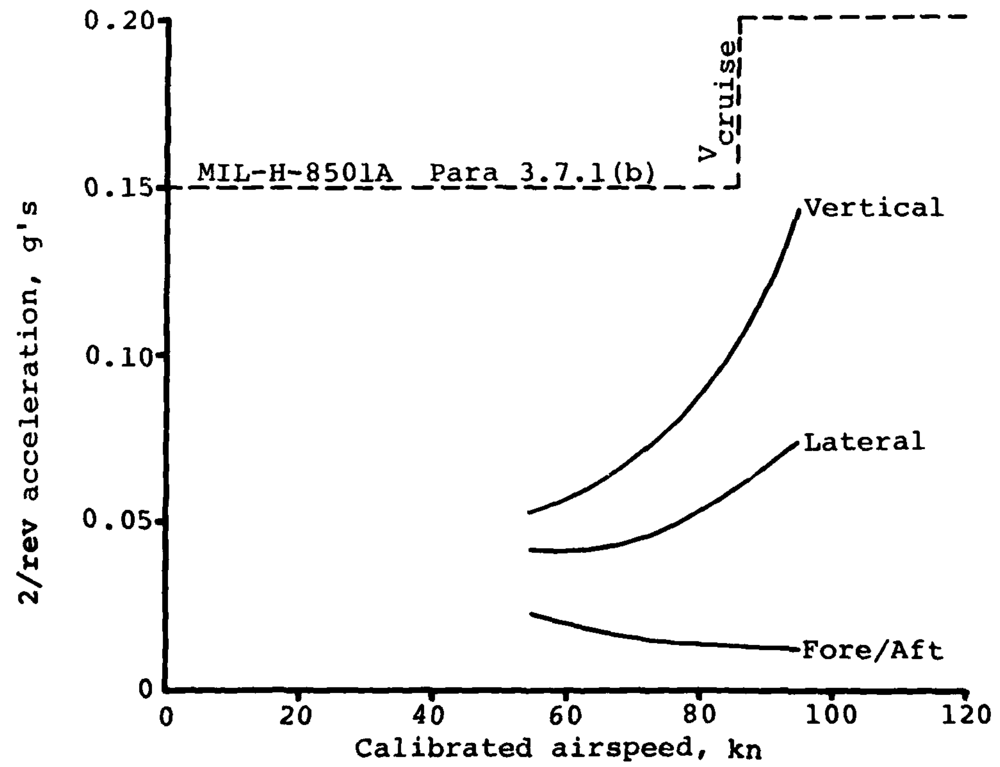


Figure 9. Pilot's seat vibration versus level flight airspeed - dummy MMS development flight test.

FLIGHT LOAD AND VIBRATION SURVEY

Complete results of the flight load and vibration survey with the dummy MMS are presented in Reference 7. No excessive loads were measured either in basic OH-58C components or in MMS components. One-per-rev vibration level was higher than that of the basic OH-58C during the dummy MMS test program. This was mainly due to the tilt and eccentricity of the dummy sight with respect to the main rotor mast axis of rotation, as discussed later. Two-per-rev vibration was slightly higher than that of a basic OH-58C, primarily because stiffer pylon and MMS focal mount springs were installed to alleviate the one-per-rev vibration problem. Time constraints prevented further testing, but it is felt that a standard OH-58C pylon spring and softer focal mount springs would have provided two-per-rev vibration levels equal to those of a basic OH-58C after the one-per-rev vibration problem had been eliminated.

Fatigue Evaluation

To provide data for a fatigue evaluation of the OH-58C helicopter with the Rockwell mast mounted sight (MMS) installed, an abbreviated flight load survey was conducted. The results of this survey are presented in Reference 7. With the exception of the components of the sight system, the fatigue strength of each component was determined from data presented in Reference 8. The fatigue strengths of the sight components were determined using conservative analytical methods. Since the flight loads survey of the OH-58 with the MMS installed was flown at only 3200 pounds gross weight, forward and aft cg, only these conditions were used to calculate fatigue lives. A 50/50 breakdown was used on flight time between forward and aft cg conditions. Some flight conditions were omitted from the complete OH-58C spectrum during the load level survey with the MMS installed. These conditions are considered to be low load conditions and their deletion should have minimal effect on the resulting fatigue life calculations.

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[7] Andrews, J., Hanson, H., Harr, H., Norvell, H., Popelka, D., Spence, W., "Flight Load and Vibration Survey of OH-58C with Mast Mounted Visionics," Part I - Test Plan, Part II - Test Results, Bell Helicopter Textron Report Number 206-099-809, Revision B, March 1980.

[8] Cassidy, B., and Norwell, J., "Fatigue Life Substantiation for the Dynamic Components of the Model 206B-1 Helicopter and the Model OH-58C Helicopter," Bell Helicopter Textron Report Number 206-099-148, February 1973.

The effects of flight loads measured during operation with the MMS installed were evaluated for the following components: M/R blade, M/R yoke, M/R mast, M/R pitch link, upper R/H cyclic tube, lower collective tube, pylon support link, pylon support fitting, and T/R blade. These components are considered representative of the most critical elements in each of the fatigue-sensitive areas of the basic aircraft. Table 5 lists these components with name, part number, endurance limit, baseline fatigue life, and fatigue life in the MMS configuration. Components having no flight loads greater than the respective endurance limit are listed with their maximum load/stress values in Table 6.

Blade Loads

The measured main rotor beam and chord loads for the OH-58C with the dummy sight installed were compared to those for the baseline OH-58C. Figures 10 and 11 present the spanwise variation of the oscillatory loads for two airspeeds at forward and aft center of gravity. The beam loads are essentially unaffected by the addition of the dummy sight; however, the chord loads are reduced for the dummy sight configuration.

The reduction in oscillatory chord loads is attributed to the increase in hub mobility due to the focal mount of the dummy sight. The first chordwise bending frequency of the rotor is highly dependent on the hub mobility. An increase in the hub mobility will increase the chordwise bending frequency, which moves it farther from resonance with the one-per-rev airload excitation. The dummy sight configuration for the flight load survey utilized a stiffer main rotor pylon mount and a stiffer MMS focal mount than the ground vibration test configuration. These stiffer mounts result in a two-per-rev hub mobility which is higher for the dummy sight configuration than for the baseline OH-58C configuration. Thus, it would be expected that the chordwise loads would be lower for the dummy sight configuration.

The chordwise bending loads at the critical blade station 60 are presented in Figure 12 for both the baseline and dummy sight configurations. The loads for the dummy sight configuration are below the endurance limits, and are generally lower than for the baseline configuration. A number of low-speed maneuvers are included which show acceptable blade loads for nap-of-the-earth operation.

Vibration

Evaluation of the vibration characteristics with the stiffer MMS focal mount plates installed and the subsequent flight load and vibration survey were conducted from September 4 through 14, 1979. The dummy sight weight was adjusted to 64 pounds by removing three of the tungsten weights to be representative of the Rockwell MMS weight projected at this time.

TABLE 5. BASIC COMPONENT FATIGUE LIFE SUMMARY

Part Name	Part Number	Endurance Limit	Fatigue Life Baseline	Fatigue Life MMS
M/R Blade	206-011-250-3	±15,495 in.-lb	12,897	Unlimited
M/R Yoke	206-010-101-9	±14,675 PSI	*	*
M/R Mast	206-010-332-9	±35,112 PSI	*	*
M/R Pitch Link	206-010-342-1	±389 lb	*	*
Upper R/H Cyclic Tube	206-001-025-19	±266 lb	180,505	1,190,476
Lower Collective Tube	206-001-524-11	±266 lb	2,800	18,650
Pylon Support Link	206-031-589-1	±1,360 lb	*	*
Pylon Support Fitting	206-031-593-1	±1,360 lb	*	*
T/R Blade	206-010-750-5	±3,626 PSI	38,462	Unlimited

*Indicates no flight loads greater than the respective endurance limit.

TABLE 6. MAXIMUM MEASURED LOADS AND STRESSES

Part Name	Part Number	Endurance Limit	Maximum Measured Loads Baseline OH-58C	MMS OH-58C
M/R Yoke	206-010-101-9	±14,675 PSI	±12,077	±9,971
M/R Mast	206-010-332-9	±35,112 PSI	±29,991	±25,999
M/R Pitch Link	206-010-342-1	±389 PSI	±348	±382
Pylon Support Link	206-031-589-1	±1,360 Lb	±957	±862
Pylon Support Fitting	206-031-593-1	±1,360 Lb	±957	±862

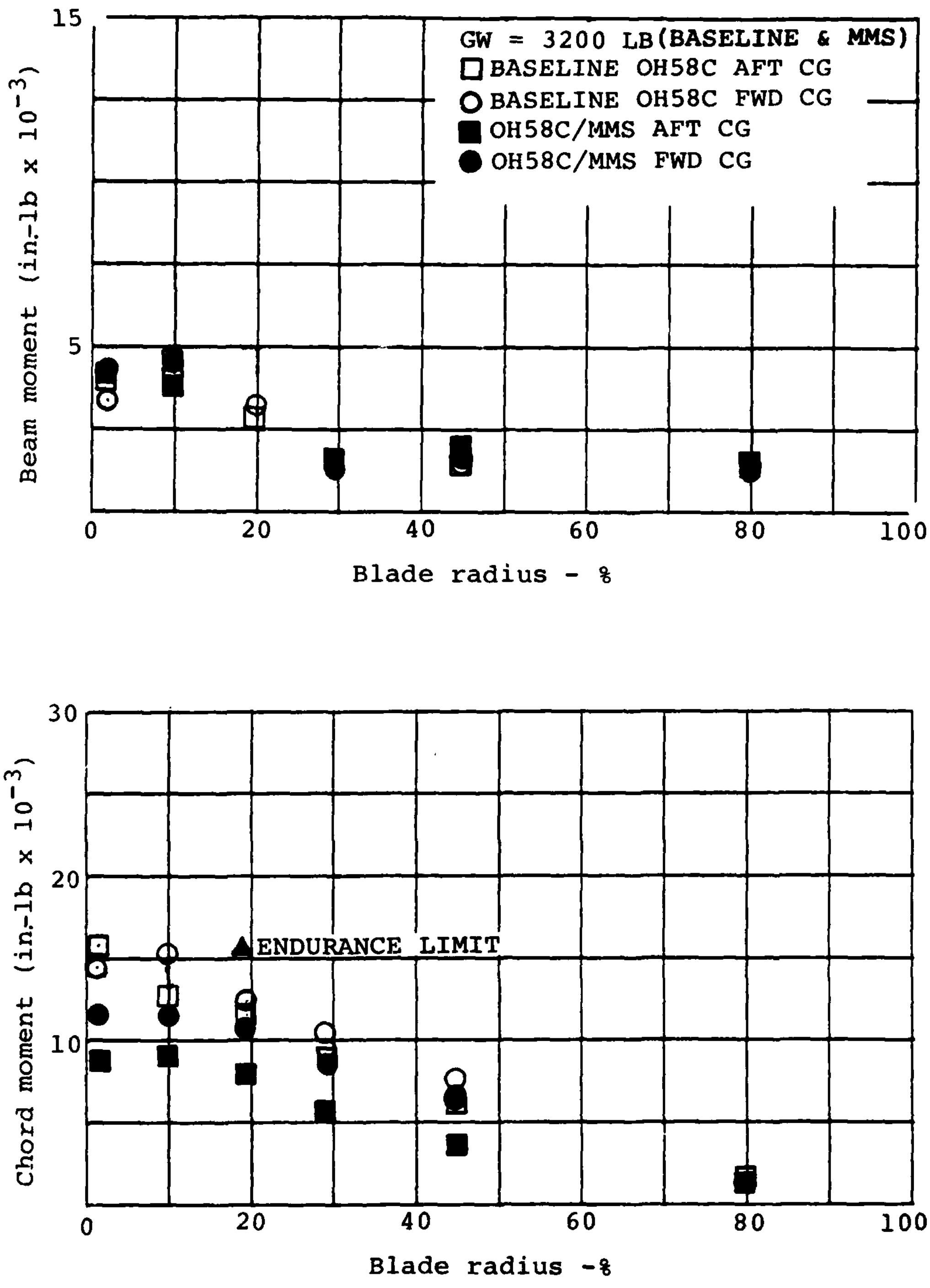


Figure 10. Comparison of main rotor oscillatory bending moments for baseline OH-58C and OH-58C/MMS at 80 kn.

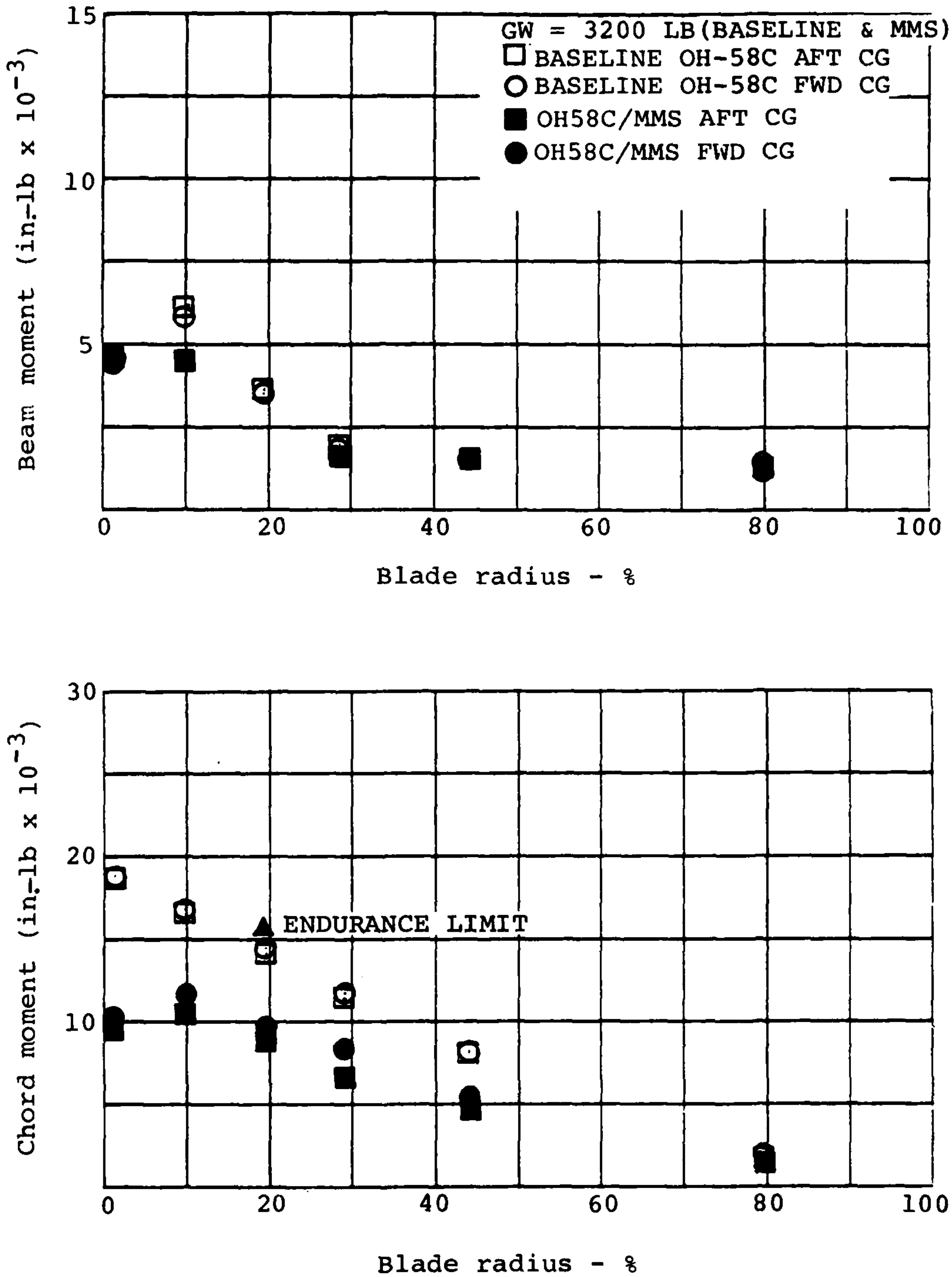


Figure 11. Comparison of main rotor oscillatory bending moments for baseline OH-58C and OH-58C/MMS at 100 kn.

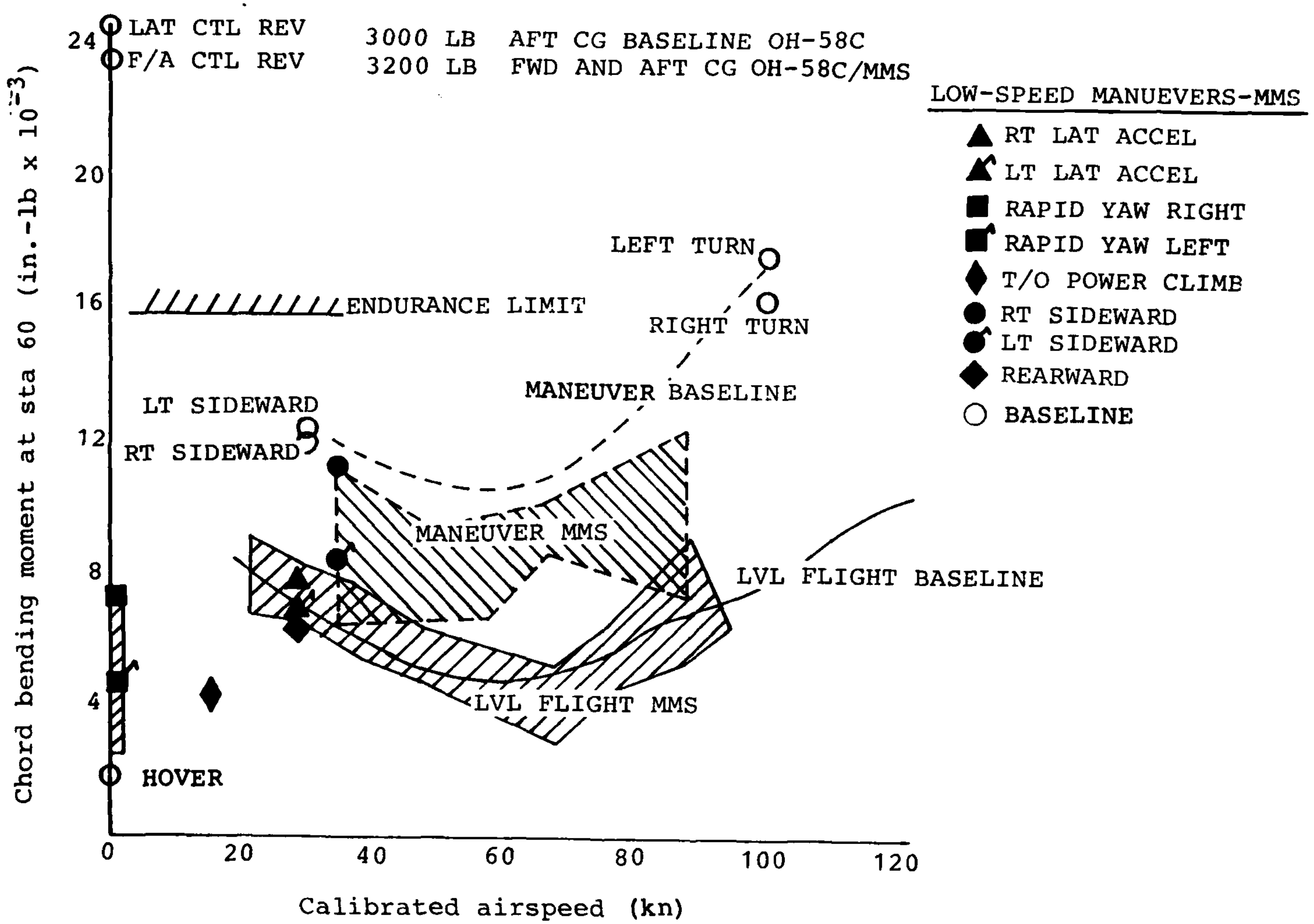


Figure 12. Comparison of measured chord bending moment at Station 60 for baseline OH-58C and OH-58C/MMS.

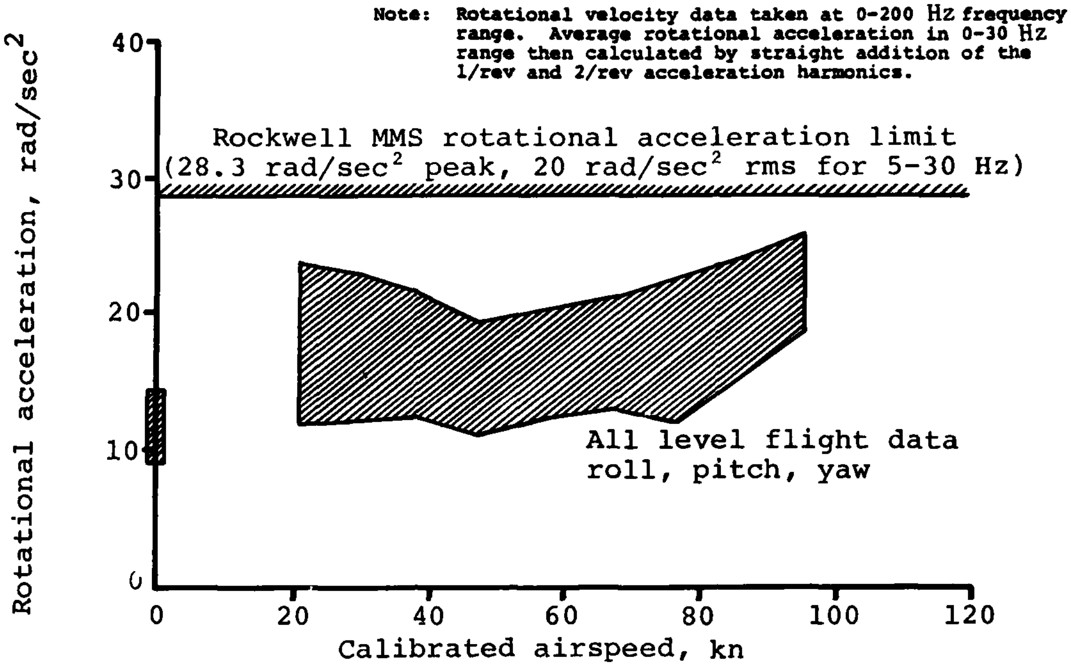
As predicted, it was found that the stiffer MMS focal plates did reduce sight two-per-rev rotational vibration. A stiffer MMS mount was then installed, which reduced sight one-per-rev rotational response sensitivity, especially in hover, but negated the reduction in sight two-per-rev rotational response which was gained by the stiffened focal plates. As a result, the one-per-rev response anomaly was somewhat desensitized but still very much in evidence.

Attention was then directed toward possible misalignment of the MMS mounting hardware on the main rotor mast axis of rotation, or perhaps a bent main rotor mast, as the source of the one-per-rev problem. Several attempts to measure these parameters with the MMS installed on the helicopter proved inconclusive. However, a compromise main rotor balance configuration was achieved so that the remainder of the feasibility testing could be accomplished without further delay. After completion of all testing with the dummy MMS, it was decided to remove the main rotor mast and MMS mounting hardware from the helicopter for bench test measurements to check runout and misalignment. It was found that the centerline through the cg of the dummy sight was not coincident with the center of rotation of the mast. A detailed description of this problem is presented on page 44.

A composite of flight vibration data taken during the load level and vibration survey, Reference 7, is shown for the MMS cg and the pilot's seat in Figures 13 and 14. MMS translational response was well below limits, and rotational response in hover was much improved. Qualitatively, both one-per-rev and two-per-rev vibration levels at the pilot's seat were somewhat higher than those on the baseline OH-58C helicopter but were acceptable for feasibility testing. Twice during the survey there was evidence of MMS stop contact, with both instances occurring during high-speed 1.5g maneuvers. Under no circumstances did the MMS static standpipe ever come into contact with the main rotor mast.

TORSIONAL STABILITY SURVEY

Ground and flight tests were conducted during September 15 through 18, 1979, to demonstrate that the OH-58C engine-governor-drive train system was torsionally stable under all speed and power conditions appropriate to operation of the helicopter with the MMS installed. The system was disturbed by pilot collective lever and rudder pedal input oscillations at the approximate system 1st torsional natural frequency during representative engine power and rotor speed conditions to evaluate torsional stability margins. The test plan and test



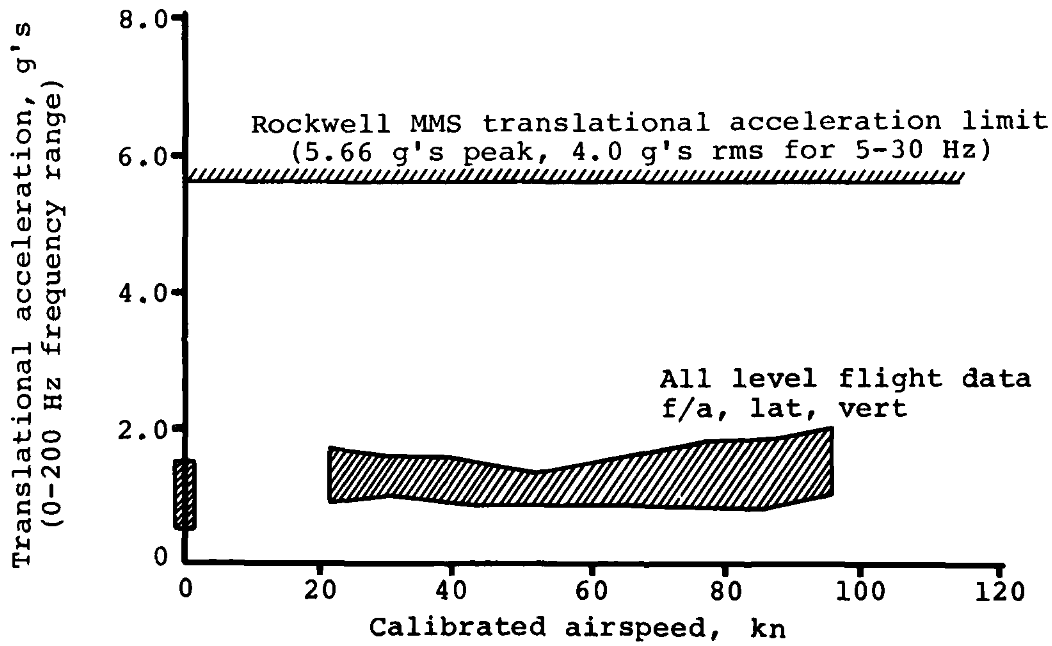


Figure 13. Dummy MMS cg average vibration versus level flight airspeed - load level and vibration survey.

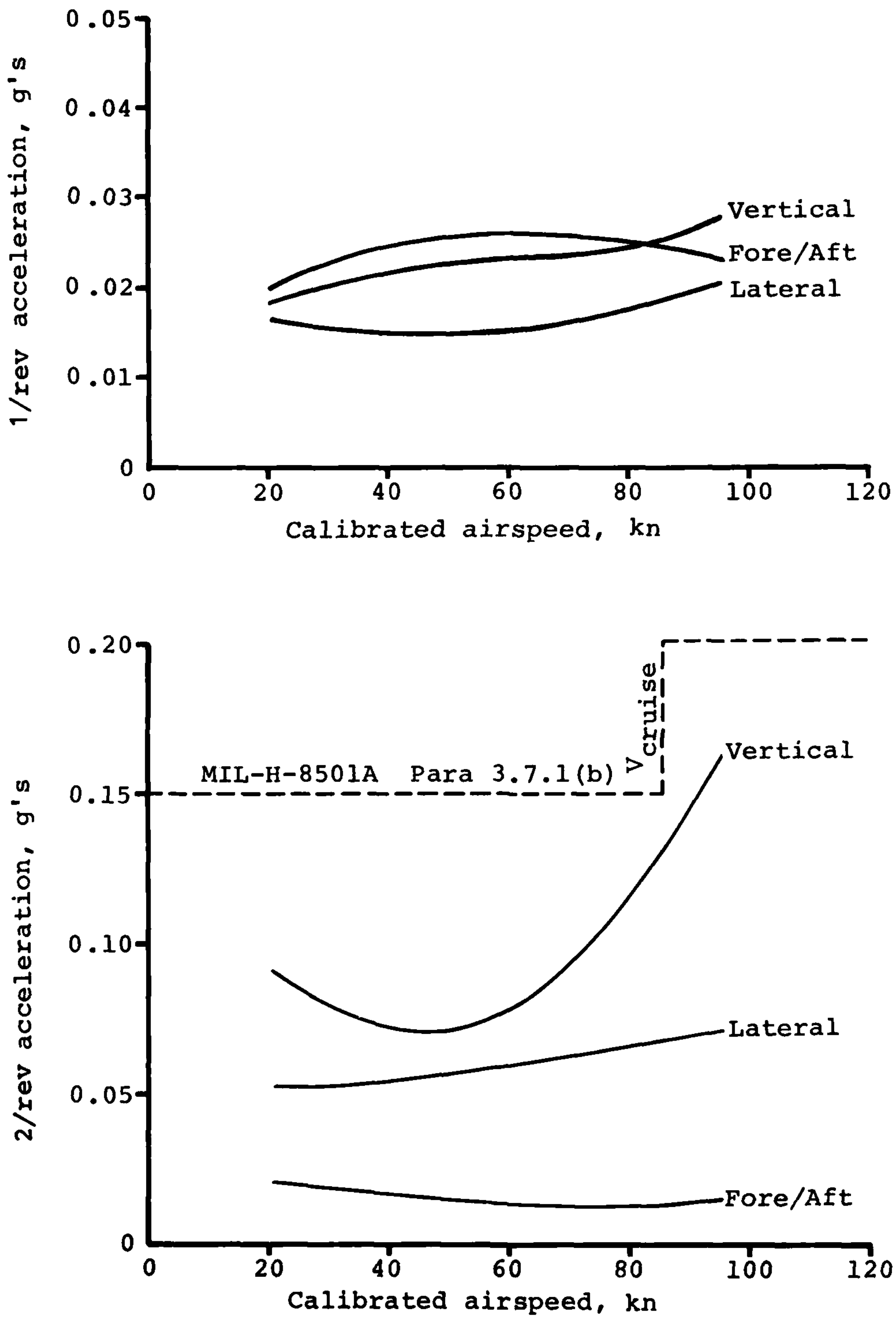


Figure 14. Pilot's seat vibration versus level flight airspeed - dummy MMS load level and vibration survey.

results are reported in Reference 9. All test conditions listed in the test plan were evaluated. In each test the main rotor mast torque oscillations were found to be positively damped and exhibited no tendency to diverge. System torsional damping characteristics for selected conditions are shown in Table 7 as compared to the same conditions for the basic OH-58C helicopter. Basic OH-58C values are given in Reference 10. It was concluded that the engine-governor-drive system of the OH-58C with MMS installed is torsionally stable and free of excessive sustained torsional oscillations throughout the flight envelope for which the helicopter is to be operated.

TABLE 7. TORSIONAL STABILITY COMPARISON

Flight Condition	Excitation	Damping (% Critical) OH-58C	Damping (% Critical) OH-58C/MMS
Hover	Collective Input	3.1	3.1
Hover	Pedal Input	3.5	3.7
48 KCAS	Collective Input	2.2	2.2
48 KCAS	Pedal Input	3.1	3.3
90 KCAS	Collective Input	3.8	2.8
90 KCAS	Pedal Input	2.4	3.1
MCT*	Collective Input	3.1	3.7
MCT*	Pedal Input	4.5	3.7

*Maximum Continuous Torque:
Basic OH-58C level flight (V_H) = 102 KCAS (Ref. 10)
OH-58C/MMS level flight = 96 KCAS (Ref. 7)

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[9]Andrews, J., and Hanson, H., "Torsional Stability Survey of the OH-58C with Mast Mounted Sight," Part I - Test Plan, Part II - Test Results, Bell Helicopter Textron Report Number 206-099-807, Revision B, March 1980.

[10]McEntire, K., "Engine/Airframe Compatibility Demonstration for OH-58C Helicopter," Bell Helicopter Textron Report Number 206-099-748, Revision A, November 1978.

HANDLING QUALITIES

The OH-58C with a dummy mast mounted sight installed on a focal mount was extensively tested to determine what handling qualities, if any, were changed by the addition of the mast mounted sight. A detailed description of the tests and test results is presented in Reference 11.

In addition to the mast mounted sight, the test helicopter was equipped with a BHT Model 206 three-axis SCAS, which improved handling qualities and provided a more stable platform for the mast mounted sight.

Handling qualities tests were conducted with a modified dummy sight installed on the focal mount as shown in Figure 15. This version of the dummy sight did not rotate (as did the original dummy) and the shape was more nearly the same as the Rockwell sight. The main rotor slip ring was not installed, as all rotating loads data on the main rotor had been taken. Main rotor flapping data could not be obtained without the slip ring. A tail rotor slip ring was installed. A nose boom was installed to provide pitot and static sources for airspeed and altitude measurements, as shown in Figure 16. The pitot head was the swiveling type which provided accurate airspeed information during helicopter sideslips. Instrumentation vanes for measuring angle of sideslip and angle of attack were also installed on the nose boom.

Tests were conducted in relatively stable air with data recorded for the following parameters:

- Static longitudinal trim stability
- Collective-fixed static longitudinal stability
- Static lateral-directional stability
- Dynamic stability
- Controllability
- Maneuver stability
- Autorotation entries

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[11]Gastinger, D., Hardesty, D., Harr, H., Hester, M., "Handling Qualities for the Model OH-58C Helicopter with Mast Mounted Visionics," Part I - Test Plan, Part II - Test Results, Bell Helicopter Textron Report Number 206-099-423, Revision C, February 1980.

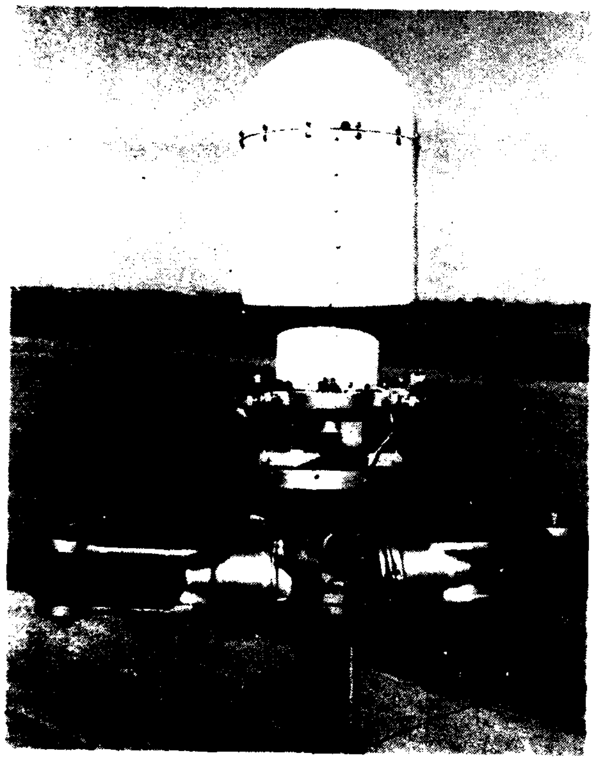

Figure 15. Nonrotating dummy sight on OH-58C.

Figure 16. OH-58C configured for handling qualities tests.

A thorough pilot qualitative evaluation was conducted during hover, sideward and rearward flight, transition and maneuvering flight. Results of the tests showed that the installation of the dummy mast mounted sight did not significantly change the handling qualities from those of the basic OH-58C.

The flight envelope of the OH-58C with the mast mounted sight installed is the same as the basic OH-58C with the following exceptions:

1. Maneuver loads at design gross weight (3200 pounds) are limited to 0.6 negative to 1.4g's positive due to increased vibration and the focal mount hitting its stops, compared to 0.5 and 2.34 for the basic OH-58C.

2. V_{ne} is limited to 100 knots indicated airspeed (KIAS) between sea level and 3000 feet density altitude. V_{ne} is reduced three knots per 1000 feet above 3000 feet density altitude. Basic OH-58C V_{ne} is 145 knots.

The gross weight (GW), center of gravity (cg) and sideslip flight envelopes are the same as those of the basic OH-58C.

PRELIMINARY AIRWORTHINESS EVALUATION

A preliminary airworthiness evaluation (PAE) was conducted on the OH-58C with the dummy mast mounted sight installed. The PAE was performed by U.S. Army personnel from the United States Army Aviation Engineering Flight Activity (USAAEFA) with support from BHT personnel at the BHT Flight Research Center. Purposes of the PAE were to verify results of BHT tests, evaluate the OH-58C with SCAS installed, and determine if the OH-58C with MMS was safe for further testing by the U.S. Army. It was concluded that the OH-58C with MMS presented no problems that would prevent continuation of the feasibility testing. Complete results of the PAE are presented in Reference 12.

[12]Bishop, J., et al, "Preliminary Airworthiness Evaluation OH-58C Helicopter Configured with a Mast Mounted Sight," USAAEFA Project Number 7809, to be published 1980.

ROCKWELL MAST MOUNTED SIGHT CONFIGURATION

GENERAL

The dummy sight and most BHT instrumentation were removed and the Rockwell mast mounted sight and associated electronics and instrumentation were installed in the OH-58C following the PAE tests. Flight tests were conducted to balance the rotor, check vibration levels, and qualitatively evaluate handling qualities. Since most of the instrumentation was removed, the helicopter tests with the Rockwell MMS were mainly qualitative comparisons of the Rockwell MMS versus the dummy MMS.

MMS HARDWARE MISALIGNMENT

During the entire flight test program with the dummy sight, it was not possible to balance the rotor and/or the dummy sight to get a good ride in the helicopter while getting a low vibration level at the sight. Improving the ride one-per-rev vibration levels resulted in increased one-per-rev levels at the sight and vice versa. A marginally acceptable compromise was achieved which was suitable for the flight test program. One theory on this anomaly was that the MMS nonrotating platform either was not installed on the mast straight or was not concentric with the M/R mast axis of rotation. Attempts to measure these parameters on the helicopter with the rotor installed proved inconclusive. When the helicopter was torn down to install the Rockwell sight, it was possible to measure the run-out of the nonrotating platform with respect to the mast.

With the parts assembled on a bench it was found that the nonrotating platform had 0.026-inch radial run-out and 0.020-inch face run-out with respect to the mast axis of rotation. This amount of run-out and tilt would cause significant one-per-rev vibration when projected to the MMS cg. In addition, it was probably amplified by the MMS focal mount which was designed to isolate two-per-rev vibration.

In order to improve the alignment of the nonrotating platform, the following parts associated with the mounting were mixed and matched:

- 2 sets of MMS hardware
- 3 M/R masts
- 2 M/R trunnions
- 2 pairs of split-cone sets

It was found that changing the trunnion made the most significant difference and reindexing the cone set resulted in a small difference. Using the best combination of the above parts, the reassembled nonrotating platform had only 0.004-inch radial run-out and 0.002-inch face run-out with respect

to the mast axis of rotation. This configuration was installed on the helicopter and was used with the Rockwell sight installation. Flight test vibration data, as discussed in the next section of this report, showed that one-per-rev vibrations were reduced significantly.

VIBRATION SURVEY

The Rockwell MMS, which weighed 73 pounds, was flight tested during December 1979. The main rotor was balanced using conventional methods; as expected, one-per-rev vibrations were greatly improved with the properly aligned MMS nonrotating platform hardware.

Quantitative vibration data of the Rockwell sight was measured using Rockwell instrumentation, and helicopter ride quality was measured using two tri-axis accelerometers installed under the pilot's and copilot's seats. Harmonic analysis of this data is presented in Appendix A of this report.

A summary of the vibration data for the Rockwell sight and the pilot's seat is shown in Figures 17 and 18. Translational response of the Rockwell sight was measured on the trunnion mount which is located inside the sight assembly at the approximate cg of the sight. The Rockwell sight fore/aft average oscillatory response is somewhat higher than was experienced with the dummy MMS. Rotational response of the sight was obtained from the line-of-sight angular accelerometer, and sight vibration data was collected only with the sight in the forward-looking position, so that only roll response data was obtained. Pilot's seat one-per-rev vibration levels are much reduced, being qualitatively the same as those of the baseline OH-58C helicopter. Pilot's seat two-per-rev vibration levels are comparable to those experienced with the dummy MMS, qualitatively still somewhat higher than on the baseline OH-58C helicopter. This is probably due to the stiffer main rotor pylon mount which was retained to reduce pylon gust response sensitivity.

HANDLING QUALITIES

Handling qualities with the Rockwell sight installed were checked qualitatively by the pilot and compared with dummy sight test results. No instrumentation for quantitative evaluation was installed with the Rockwell sight.

This evaluation showed no significant difference in handling qualities between the dummy sight and the Rockwell sight installations. The only noticeable difference was a slight steady roll oscillation above 65 KIAS at a frequency of one to two Hertz with one to two degrees amplitude. This was partially due to the change in drag caused by the flat lens of the sight turning back and forth. This effect was reduced after the sight yawing oscillation was fixed by eliminating

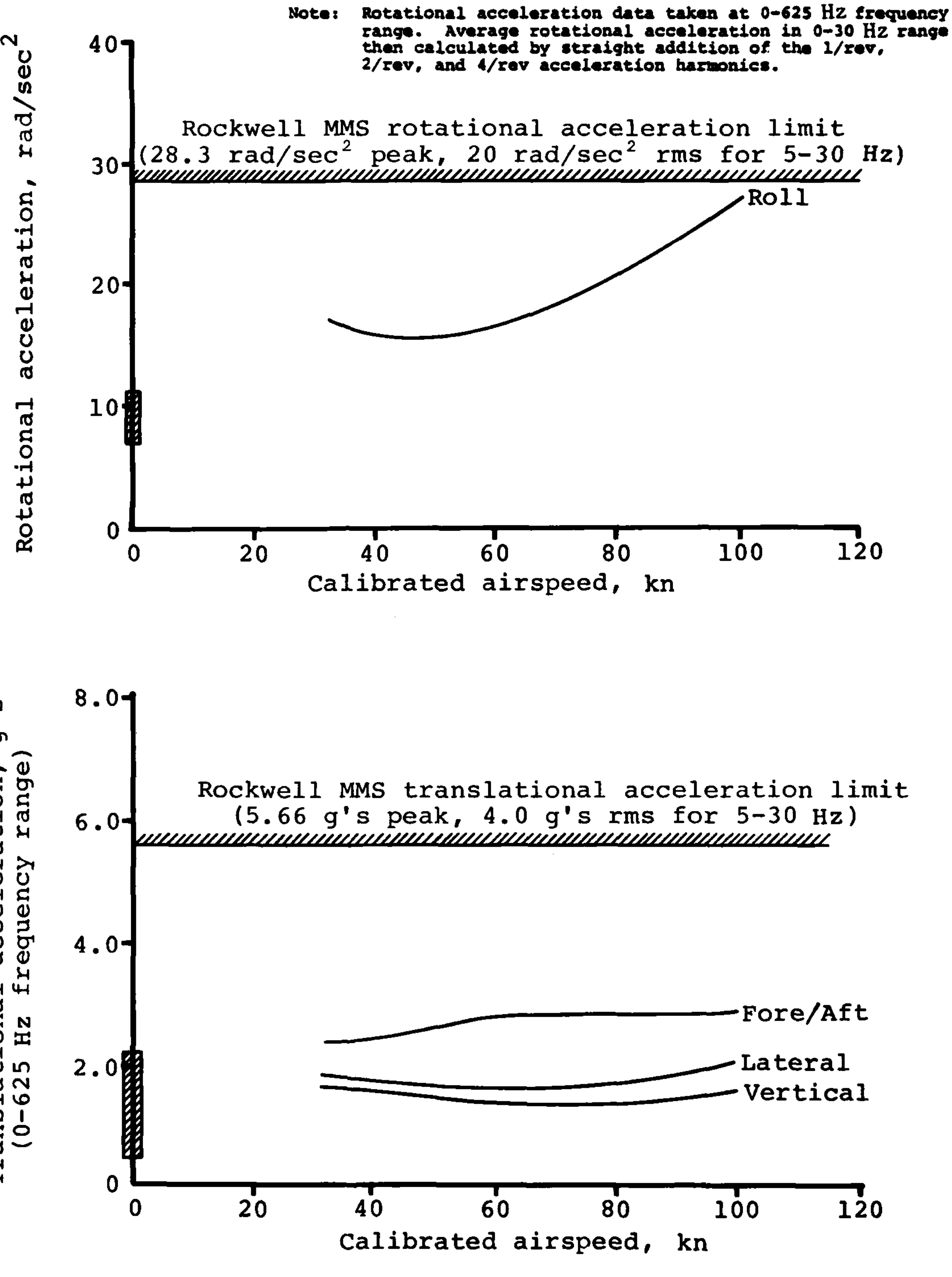

Figure 17. Rockwell MMS average vibration versus level flight airspeed - vibration survey.

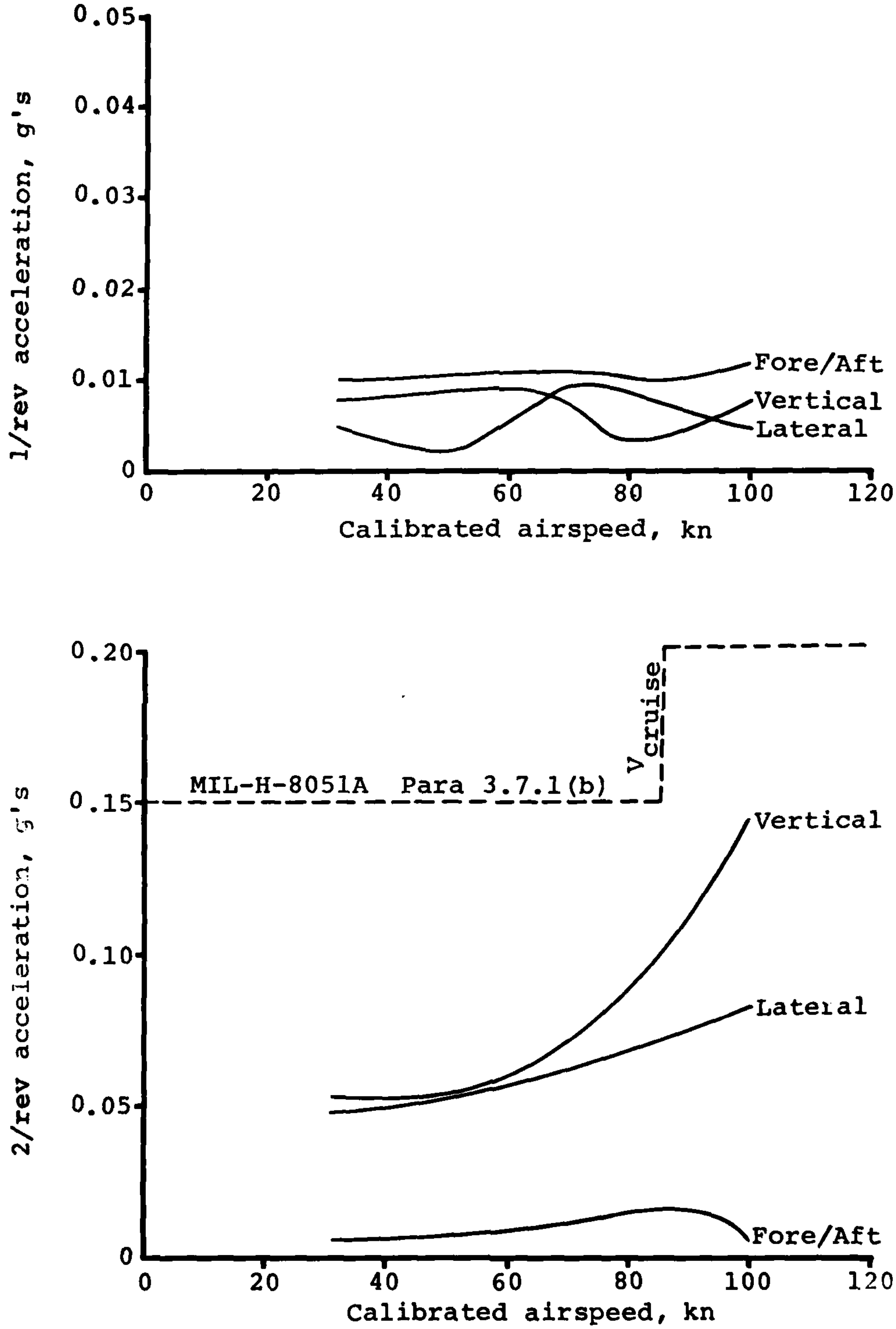

Figure 18. Pilot's seat vibration versus level flight airspeed - Rockwell MMS vibration survey.

the looseness in the standpipe splines (discussed in the following section).

Subsequent testing of the SCAS on other OH-58C helicopters indicates that this oscillation can be further reduced by changes in the SCAS yaw channel. These changes will be incorporated in the MMS helicopter.

PRELIMINARY SIGHT EVALUATION

The Rockwell sight was operated first with the helicopter on the ground, using an external electrical power source and with the helicopter rotor not turning. Following this check the sight was operated with the helicopter on the ground, using helicopter electrical power and the rotor turning at normal operating rpm. A 4-foot by 4-foot high resolution target located 500 meters away was used to check the vertical and horizontal resolution of the system.

Results of these tests indicated satisfactory operation of the Rockwell system; however, it was found that the sight oscillated or "hunted" back and forth approximately 7 degrees peak-to-peak at approximately 5 Hertz. This sight yawing oscillation did not produce a noticeable effect on the TV picture, but it was considered unacceptable for the following reasons:

1. It produced stabilization errors in the sight of 10 to 30 microradians peak-to-peak which degrade recognition performance.

2. It cyclically torqued the standpipe with greater than 40 in.-lb impulse loads.

3. It produced excessive wear and heating in the sight servo system.

4. It looked bad.

The oscillation was caused by the sight azimuth servo system reacting to the looseness of the standpipe splines. A temporary fix was incorporated which eliminated the oscillation. The splines at the lower end of the standpipe were bonded together and Teflon tape was added to the spline at the upper end. These steps eliminated the cause of the problem by greatly reducing the free play in the splines. A system of spring loading the splines appears to be the ideal way of overcoming this problem in future designs.

ROCKWELL FLIGHT TEST

In order to evaluate MMS performance, recognition and detection target boards (see Figure 19) were fabricated and installed side by side on 8-foot-high supports as shown in

Figure 20. Targets were designated A, B, C, D from left to right. The stripes on the targets were painted white and gray, with a contrast ratio of 20 percent. The targets faced the east to provide front-lighting in the morning and back-lighting in the afternoon. Range to the targets was marked off in 500-meter increments by white X's and numbers painted on the road running perpendicular to the targets, beginning 3000 meters from the targets.

Tests were conducted with the helicopter at low altitude (100 feet to 200 feet) coming to a hover over the "X" marks every 500 meters. Tests were also conducted with the helicopter flying toward the targets at approximately 80 knots. Sight performance is shown in Table 8.

TABLE 8. ROCKWELL SIGHT PERFORMANCE

Performance	Range (Kilometers) NFOV	WFOV
Detect 8-ft x 8-ft Target Boards	15	--
Detect Targets A & B (Resolve 2 Line Pairs)	6	0.5
Recognize Targets C & D (Resolve 6 Line Pairs)	3	0.3

Conditions

Weather: Clear, Unlimited Visibility

Target: Front Lighted

Helicopter: Hover

NOTE:

NFOV = Narrow Field of View
WFOV = Wide Field of View

Back-lighting the targets (afternoon flights) degraded the resolution approximately 500 meters. Flying toward the targets at closing speeds up to 80 knots also degraded resolution by approximately 500 meters.

In addition to the tests run with the target boards, the sight was used to track moving trucks and automobiles on a nearby freeway. Only a qualitative evaluation was made of the tracking system, with good results on vehicles moving somewhat

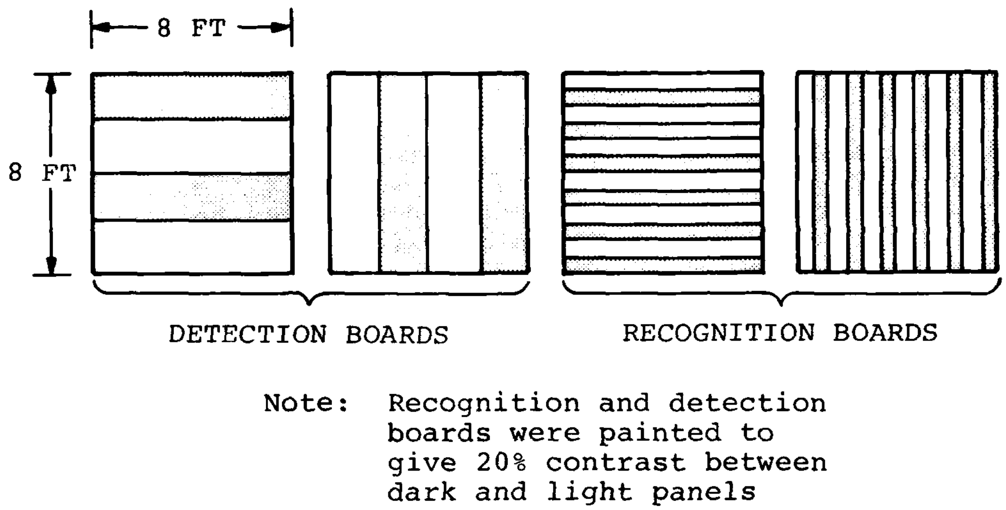

Figure 19. Recognition and detection boards.

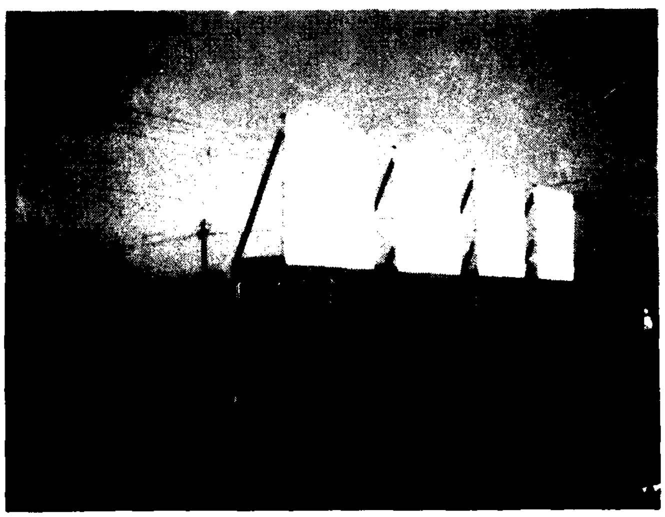

Figure 20. Target boards installed for Rockwell sight evaluation.

toward or away from the line of sight of the camera. The MMS operator had trouble locking onto close-in vehicles traveling at right angles to the line of sight; however, once the MMS locked onto a vehicle, it was able to track it through 90 degrees to the line of sight.

The only problem noted with the Rockwell sight was its inability to rotate forward from a 90-degree or aft position at helicopter speeds above 70 knots. This anomaly was apparently due to the aerodynamic forces acting on the flat plate area of the sight lens and laser cooler exceeding the slew torque capability of the outer azimuth gimbal.

Video tapes made during target board and tracking test-runs showed good resolution and contrast. The overall performance of the Rockwell MMS TV system on the OH-58C was very satisfactory. The laser was fired at BHT only during EMC tests. The lens cover was kept in place during the laser firings.

EMC TESTS

Electromagnetic compatibility (EMC) tests were conducted on the bailed OH-58C with the Rockwell MMS and BHT SCAS installed. The results of these tests are presented in Reference 13.

The OH-58C avionics and electrical system were first examined as a source of electromagnetic interference (EMI) with the MMS TV and SCAS as victims of this interference. The tests were repeated by operating the MMS TV and then the SCAS and checking the other two systems for interference.

The laser was fired with the protective cover over the lens as a noise source while checking the other systems as interference victims. Some slight interference from the laser cooler blower was picked up by the FM receivers when operated on external power.

Results of all tests showed no significant electromagnetic interferences between the basic OH-58C systems, the MMS, and the SCAS while using the helicopter electrical system as the power source.

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[13]Wright, C., "Electromagnetic Compatibility Test Report of Rockwell Mast Mounted Sight and SAS on OH-58C Helicopter," S/N 40435(69-16214), Bell Helicopter Textron Report Number 206-099-851, Revision A, January 1980.

WEIGHT AND BALANCE

Weight and balance of the OH-58C with the mast mounted sight are presented in Reference 14 for both the dummy sight installation and for the Rockwell sight installation. Tables 9, 10, and 11 and Figure 21 present the weight and balance for the helicopter with the Rockwell system (as delivered to the Army).

[14] Pressley, J. D., "Estimated Weight and Balance Report for Prototype OH-58C Aircraft with Mast-Mounted Sight," Bell Helicopter Textron Report Number 206-099-352, Revision B, November 1979.

TABLE 9. DERIVATION OF MAST MOUNTED SIGHT WEIGHT AND BALANCE

	Weight	Long Arm	Long Moment	Vert Arm	Vert Moment
Sensor & focal mount:	(92.1)		(9711)		(12964)
Rockwell sight	73.0	105.4	7694	144.0	10512
Focal mount (206-812-010-105)	19.1	105.6	2017	128.4	2452
Standpipe & adapter installation:	(16.1)		(1721)		(1933)
Standpipe assy (206-840-004-109)	3.1	108.5	336	100.6	312
Spacer (206-840-004-107)	0.5	106.7	53	123.8	62
Support assy (206-840-005-1)					
Adapter (206-840-004-117)	4.6	106.5	490	125.5	577
Housing (206-840-004-119)	4.1	106.7	437	123.2	505
Nut (206-840-004-121)	1.1	106.5	117	125.5	138
Spacer set (206-840-004-123)	1.1	106.6	117	124.5	137
Baffle (206-040-004-129)	0.1	106.5	11	125.9	13
Nut (214-040-246-1)	0.1	106.8	11	122.6	12
Bearings (2) (60112RSJMB01)	2.2	106.6	235	123.4	271
Remove mast nut	-0.8	107.0	-86	117.6	-94
Monitor units installation	(52.5)		(3186)		(2462)
Monitor - pilot	8.0	40.6	325	50.0	400
Monitor - observer	29.3	50.2	1471	42.0	1231
Monitor - passenger	14.2	95.0	1349	55.0	781
Pilot monitor mount	1.0	40.6	41	50.0	50
Instrumentation units installation:	(196.5)		(21619)		(7762)

TABLE 9. - Continued

	Weight	Long Arm	Long Moment	Vert Arm	Vert Moment
Video tape recorder	19.5	107.0	2087	53.0	1034
Magnetic tape recorder	24.0	149.0	3576	42.0	1008
Shock mount	2.5	149.0	373	42.0	105
Tracker & power supply	59.0	104.7	6177	36.9	2177
Interface/servo electronics	48.5	85.4	4142	34.0	1649
Shelf instl	3.0	96.5	290	48.0	144
Magnetic tape converter	5.5	152.0	836	34.0	187
Time code generator	7.3	102.7	750	46.0	336
Junction box	2.0	132.0	264	41.5	83
Characteristic generator	9.2	102.7	945	44.0	405
Inverter	3.4	133.0	452	41.5	141
Capacitor	2.0	142.0	284	34.5	69
Audio box	2.0	150.0	300	37.0	74
Plywood base (bulkhead)	2.9	130.0	377	43.0	125
Plywood (floor)	3.0	149.0	477	34.0	102
Switch box	0.1	146.0	15	33.5	4
Power supply	1.3	131.0	170	41.5	54
Control box	1.0	98.0	98	50.0	50
Control	0.3	119.0	36	51.0	15
Cable assemblies:	(25.0)		(2283)		(955)
Cable assy					
(206-875-005-1)	11.5	101.0	1162	36.0	414
(206-875-005-2)	0.9	96.0	86	36.0	32
Cable assy (206-875-005-3)	0.5	45.0	23	46.0	23
Cable assy (206-875-005-4)	3.7	69.0	225	39.0	144
Cable assy (206-875-005-5)	0.5	106.0	53	45.0	23
Cable assy (206-875-005-6)	0.7	78.0	55	39.0	27
Cable assy (206-875-005-7)	0.5	107.0	54	45.0	23
Cable assy (206-875-005-8)	0.4	100.0	40	54.0	22

TABLE 9. - Concluded

	Weight	Long Arm	Long Moment	Vert Arm	Vert Moment
Cable assy (206-875-005-9)	1.4	115.0	161	37.0	52
Cable assy (206-875-005-10)	1.7	60.0	102	43.0	73
Weight Delta/Army	3.2	91.3	292	38.2	122
Transmission modifications:	(1.5)		(166)		(111)
Fitting (206-840-004-105)	0.9	110.9	100	74.0	67
Support assy (206-840-004-101)	1.5	110.9	166	74.0	111
Remove support assy (206-040-152-1)	-0.9	110.9	-100	74.0	-67
Modification to fuselage:	(3.5)		(403)		(253)
Drag pin (206-032-509-5)	1.8	116.0	209	72.0	130
Roof modification (206-830-172-1)	2.8	115.0	322	72.0	202
Remove drag pin	-1.1	116.0	-128	72.0	-79
Anti-torque modification:	(36.4)		(4696)		(1724)
SCAS (206-706-305-21)	25.8	115.7	2989	41.0	1058
Directional hyd control (206-706-060-5)	8.8	159.8	1406	64.0	563
Modification (206-961-075-1)	1.8	167.3	301	57.0	103
Remove KY-28 shock mounts:	(-2.0)		(-292)		(-64)
Mount (MT-3802/ARC)	-1.6	144.0	-230	32.0	-51
Mounting plates (206-075-574)	-0.4	154.0	-62	32.0	-13
Total modification	421.6	103.2	43493	66.7	28100

TABLE 10. DERIVATION OF BASIC WEIGHT

	Weight	Long Arm	Long Moment	Vert Arm	Vert Moment
OH-58C basic weight	1922.8	114.80	220750	65.2	125367
Remove:					
Pilot seat back armor	-24.5	77.0	-1887	43.0	-1054
Pilot seat bottom armor	-11.6	66.0	-766	30.0	-348
Copilot seat back armor	-24.5	77.0	-1887	43.0	-1054
Copilot seat bottom armor	-9.4	66.0	-620	30.0	-282
Pilot side armor	-15.1	71.0	-1072	44.0	-664
Copilot side armor	-15.2	71.0	-1079	44.0	-669
Add:					
Mast-mounted sight modification	+421.6	103.2	+43493	66.7	+28100
Revised basic weight	2244.1	114.49	256932	66.57	149396

TABLE 11. GROSS WEIGHT AND BALANCE CALCULATIONS

	Weight	Long Arm	Long Moment	Vert Arm	Vert Moment
Basic weight	2244.1	114.5	256932	66.6	149396
Add:					
Pilot	200.0	65.0	13000	43.0	8600
Observer	200.0	65.0	13000	43.0	8600
Passenger	200.0	104.0	20800	43.0	8600
Passenger seat provisions	10.0	107.0	1070	33.0	330
Engine oil	12.5	108.0	2250	82.0	1025
Fuel (JP-4)	333.4	114.6	38208	28.4	9469
Mission gross weight	3200.0	107.89	345260	58.13	186020
Remove:					
Fuel	-333.4		-38208		-9469
Most forward C.G.	2866.6	107.11	307052	61.59	176551
Mission gross weight	3200.0		345260		186020
Remove:					
Observer	-200.0	65.0	-13000	43.0	-8600
Passenger	-200.0	104.0	-20800	43.0	-8600
Passenger seat provisions	-10.0	107.0	-1070	33.0	-330
Change pilot weight to 170 lb:					
Pilot	-30.0	65.0	-1950	43.0	-1290
Add:					
Fuel to full	+123.5		+15185		+4636
Most aft C.G.	2883.5	112.23	323625	59.59	171836

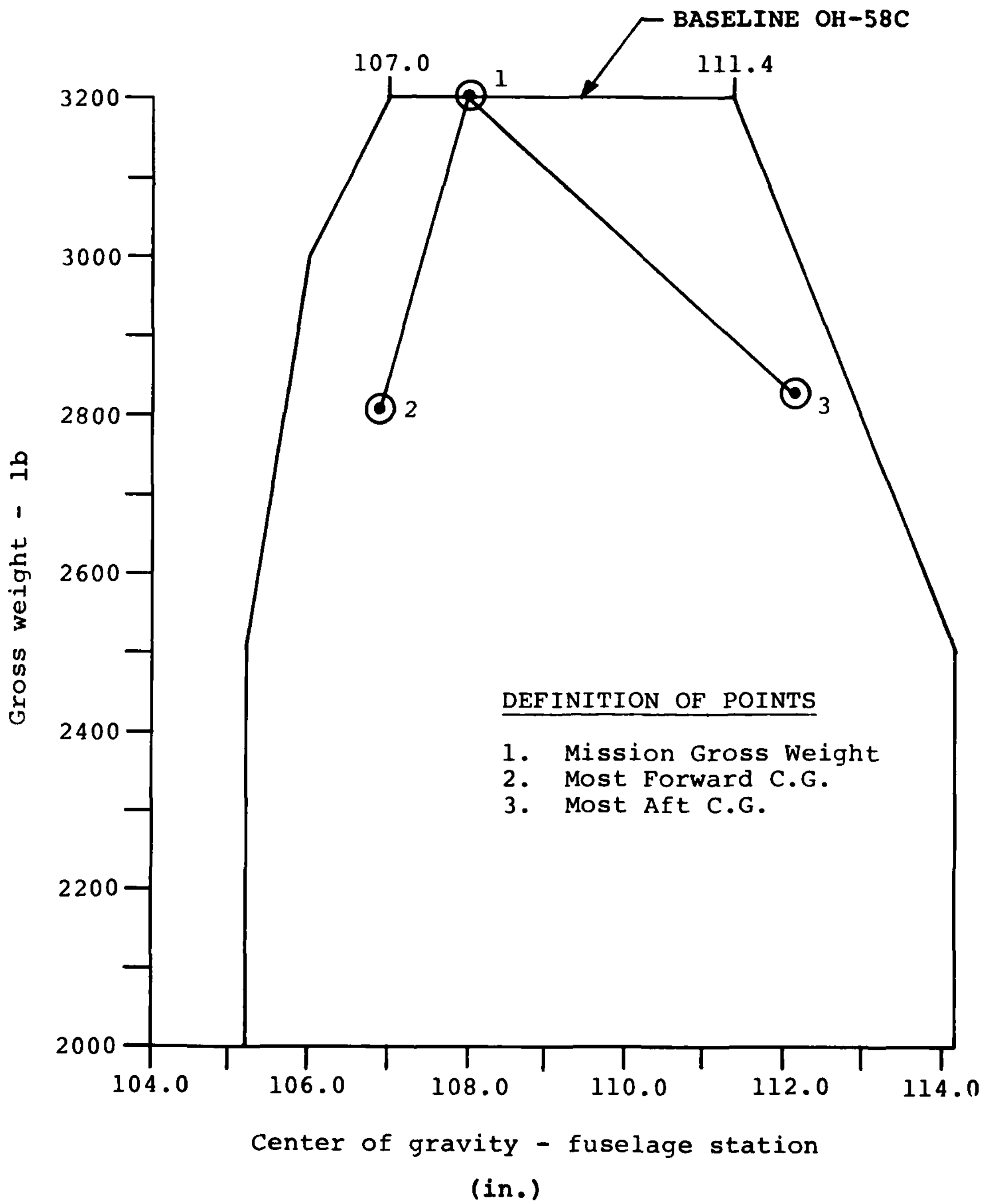

Figure 21. OH-58C with MMS gross weight versus center of gravity plot.

CONCLUSIONS

This program has demonstrated that a mast mounted sight weighing 73 pounds can be successfully installed and operated 2 feet above the rotor on an OH-58C helicopter. One of the more challenging tasks in this program was to meet the Rockwell sight translational and rotational vibration limits while minimizing increases in helicopter component dynamic loading. An isolation system (focal mount) was required between the sight and the rotor hub to keep the sight vibration levels within acceptable limits and to prevent large increases in blade loads. Helicopter speed in level flight using maximum power was reduced from 99 to 96 KCAS due to the drag of the MMS. V_{ne} was limited to 100 KCAS and maximum maneuver load factor was limited to 1.4g to preclude excessive vibration and to prevent the MMS focal mount from hitting its stops. The translational vibrations in level flight did not exceed 50 percent of the limit values, and roll rotational vibrations approached the limit in calm air at the higher airspeeds. In general, component loading with the focal mounted MMS was lower than that of the baseline OH-58C.

The criterion limiting the weight and/or height of the focal mounted MMS was the crash load factor of the existing main rotor mast, transmission, pylon support and other critical helicopter structure. Redesign of these components to accommodate a MMS would permit a considerable increase in allowable weight/height of future mast mounted sights.

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APPENDIX A

VIBRATION DATA WITH ROCKWELL SIGHT INSTALLED

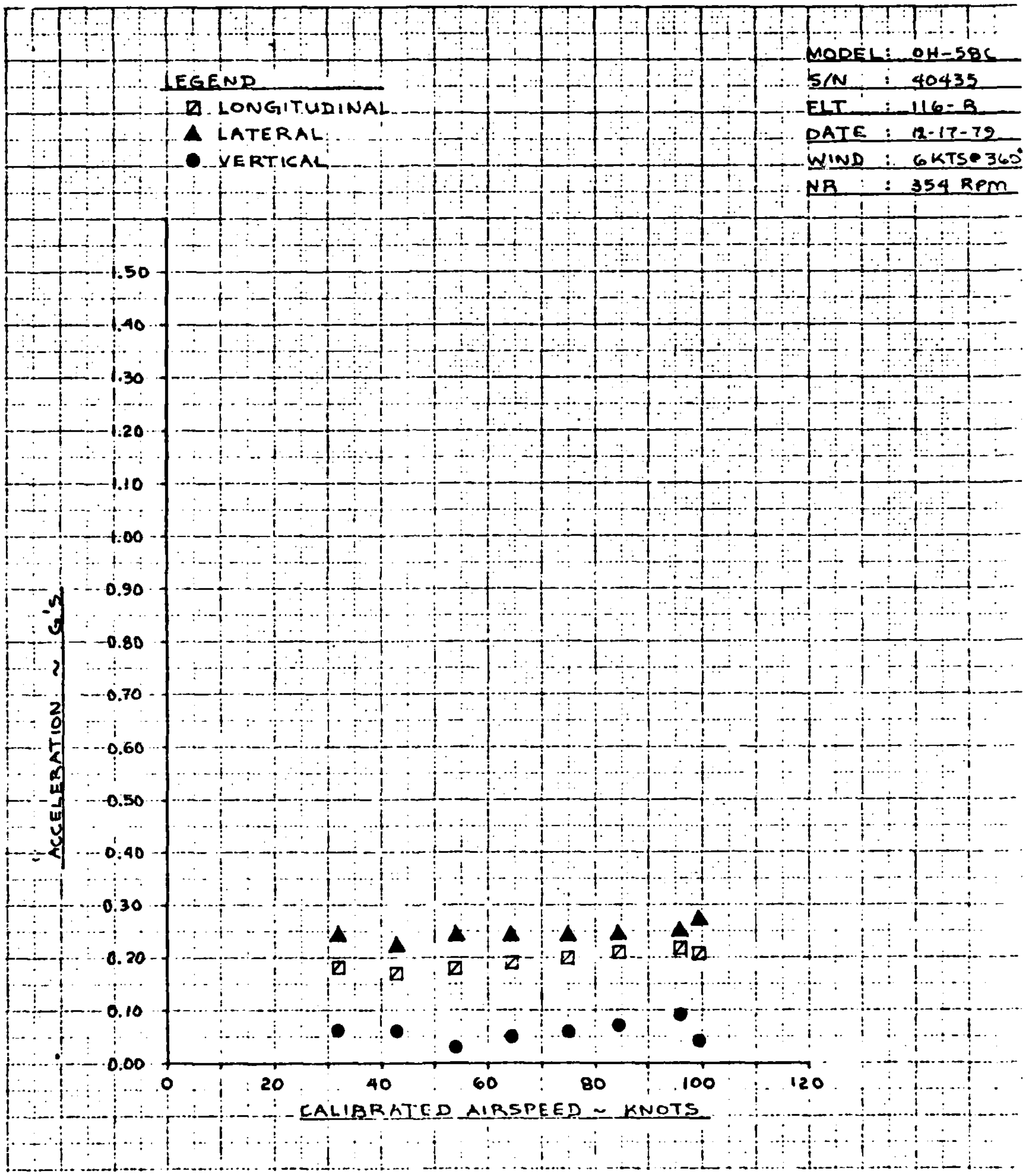

Figure A-1. Rockwell MMS trunnion (cg) vibration at M/R 1/rev versus airspeed.

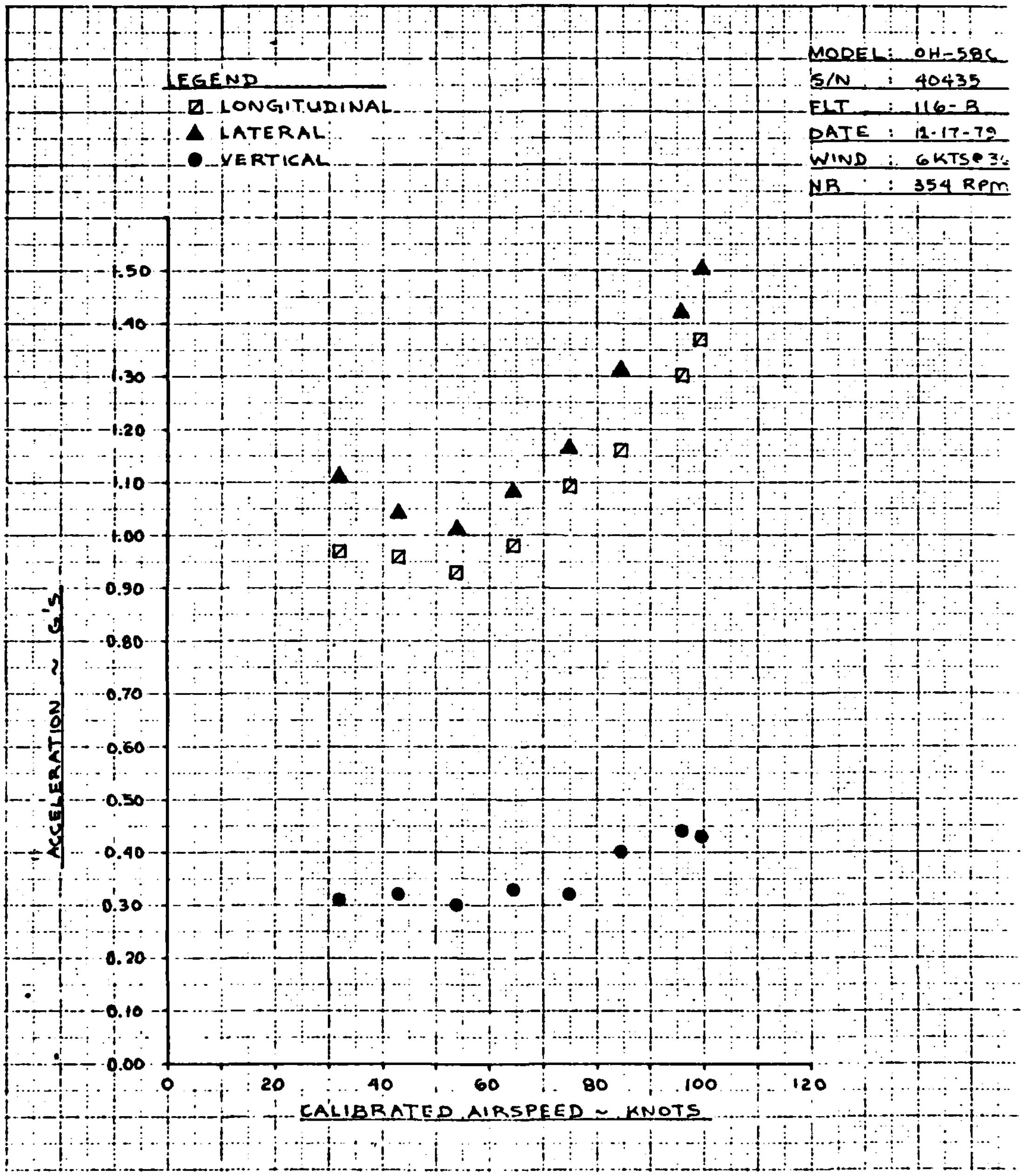

Figure A-2. Rockwell MMS trunnion (cg) vibration at M/R 2/rev versus airspeed.

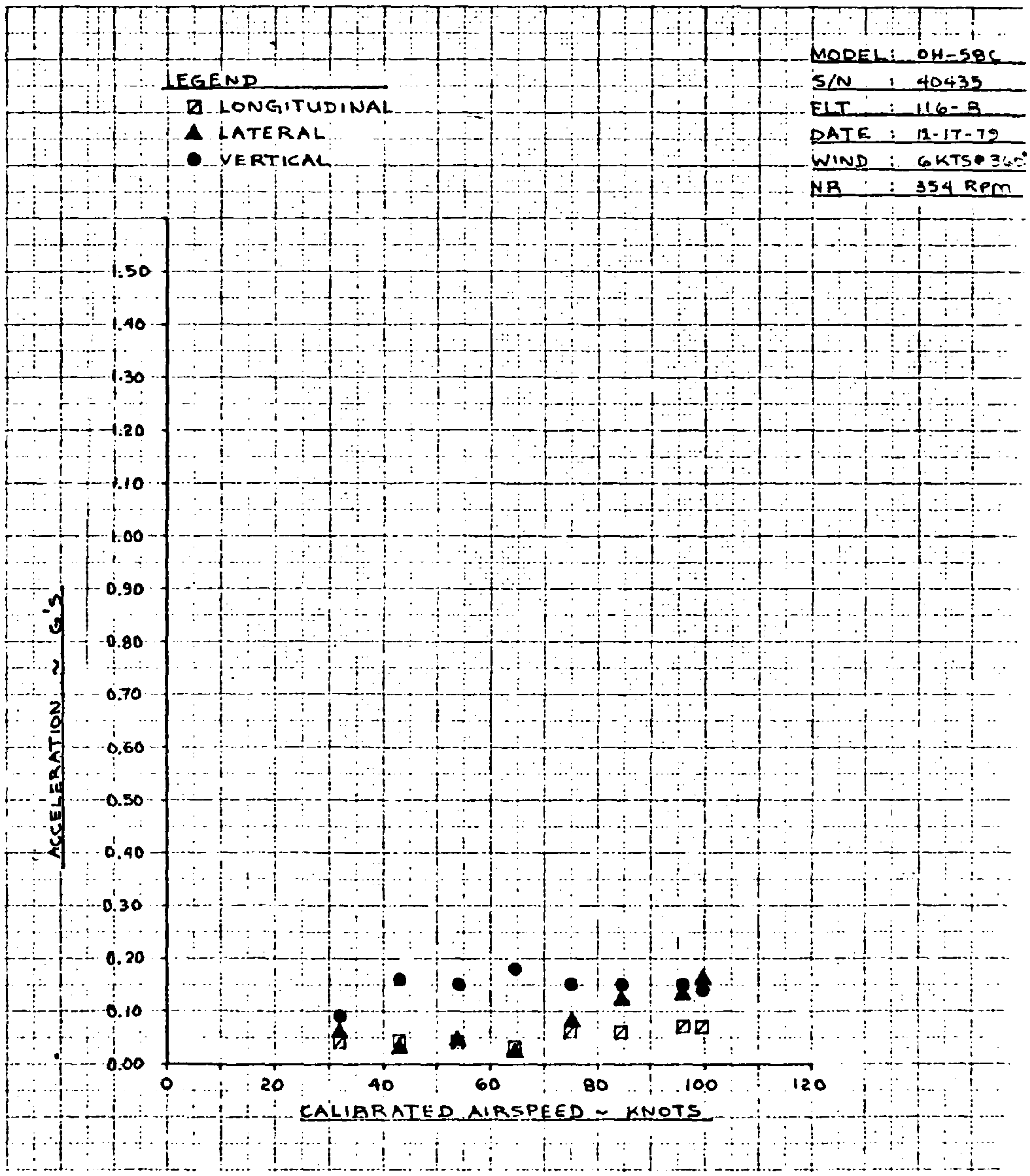

Figure A-3. Rockwell MMS trunnion (cg) vibration at M/R 4/rev versus airspeed.

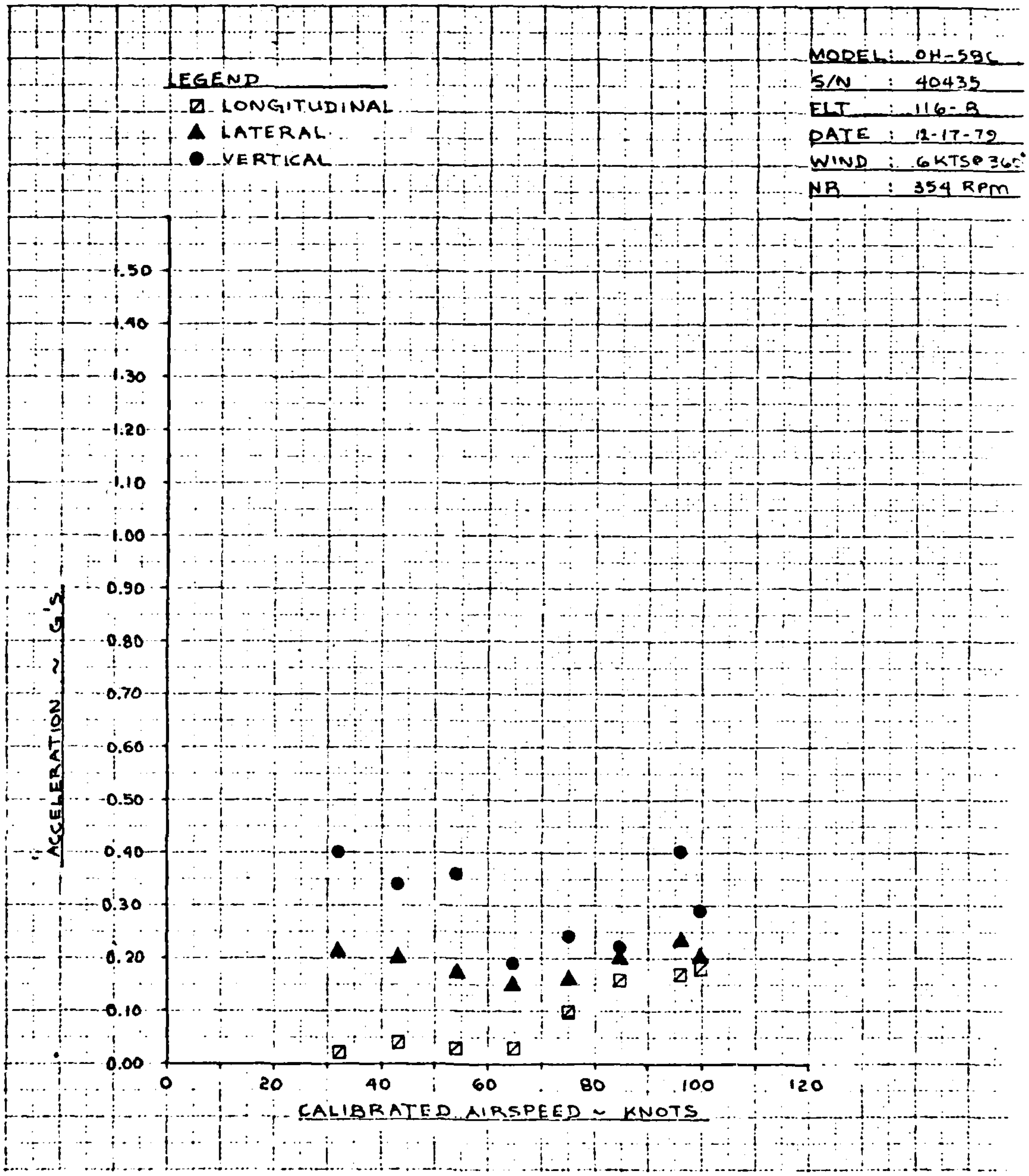

Figure A-4. Rockwell MMS trunnion (cg) vibration at M/R 6/rev versus airspeed.

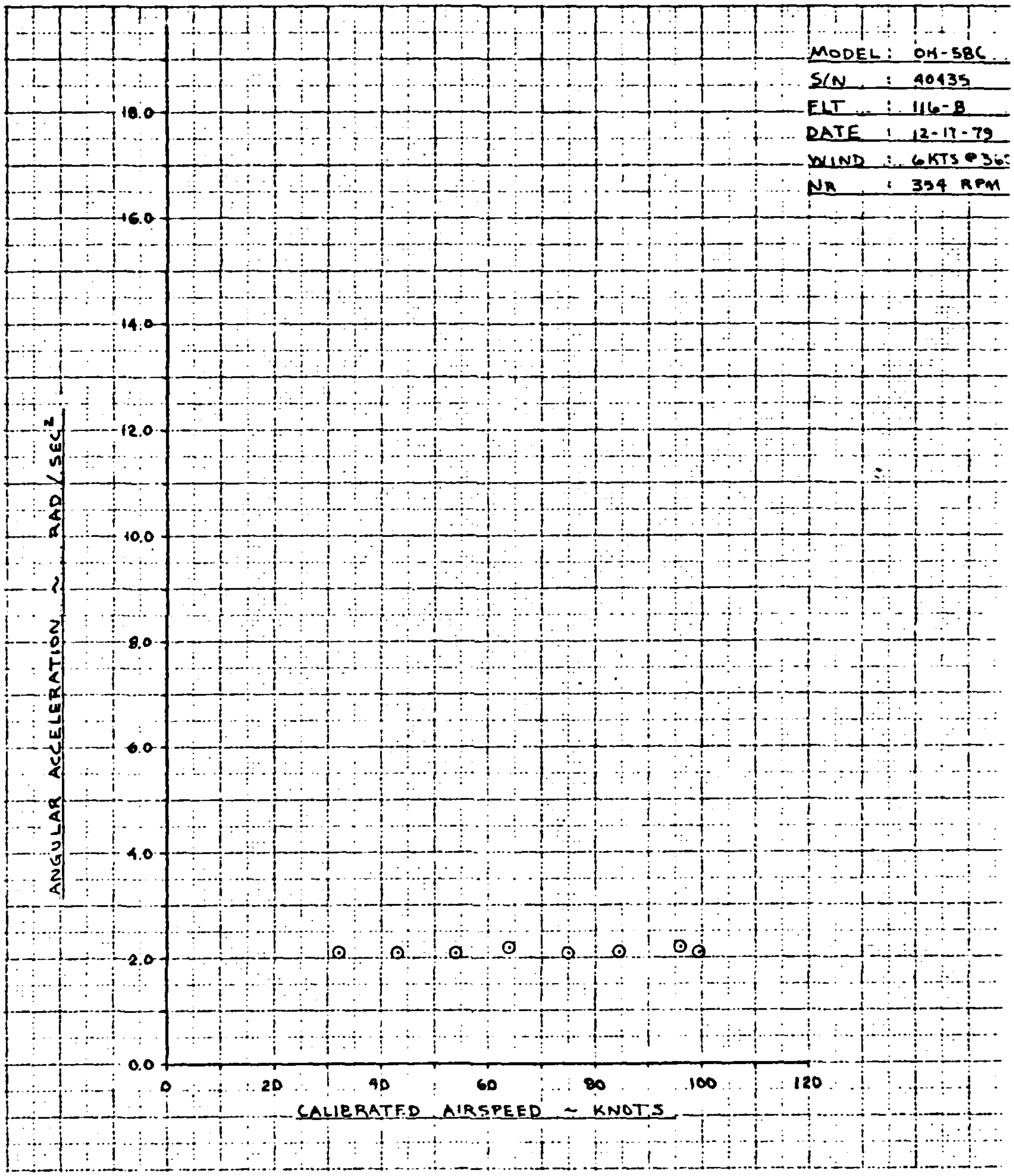

Figure A-5. Rockwell MMS line-of-sight (roll) vibration at M/R 1/rev versus airspeed.

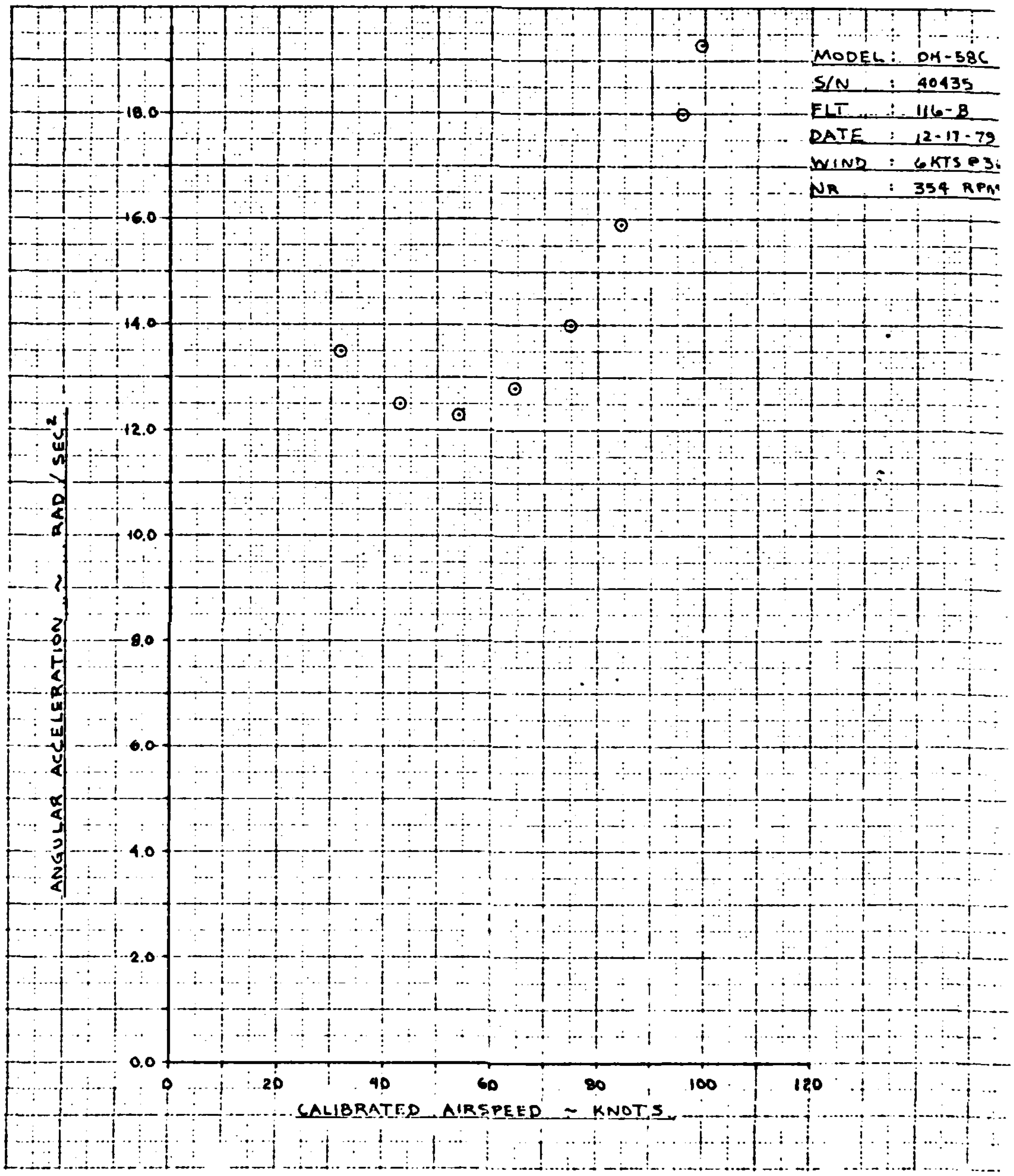

Figure A-6. Rockwell MMS line-of-sight (roll) vibration at M/R 2/rev versus airspeed.

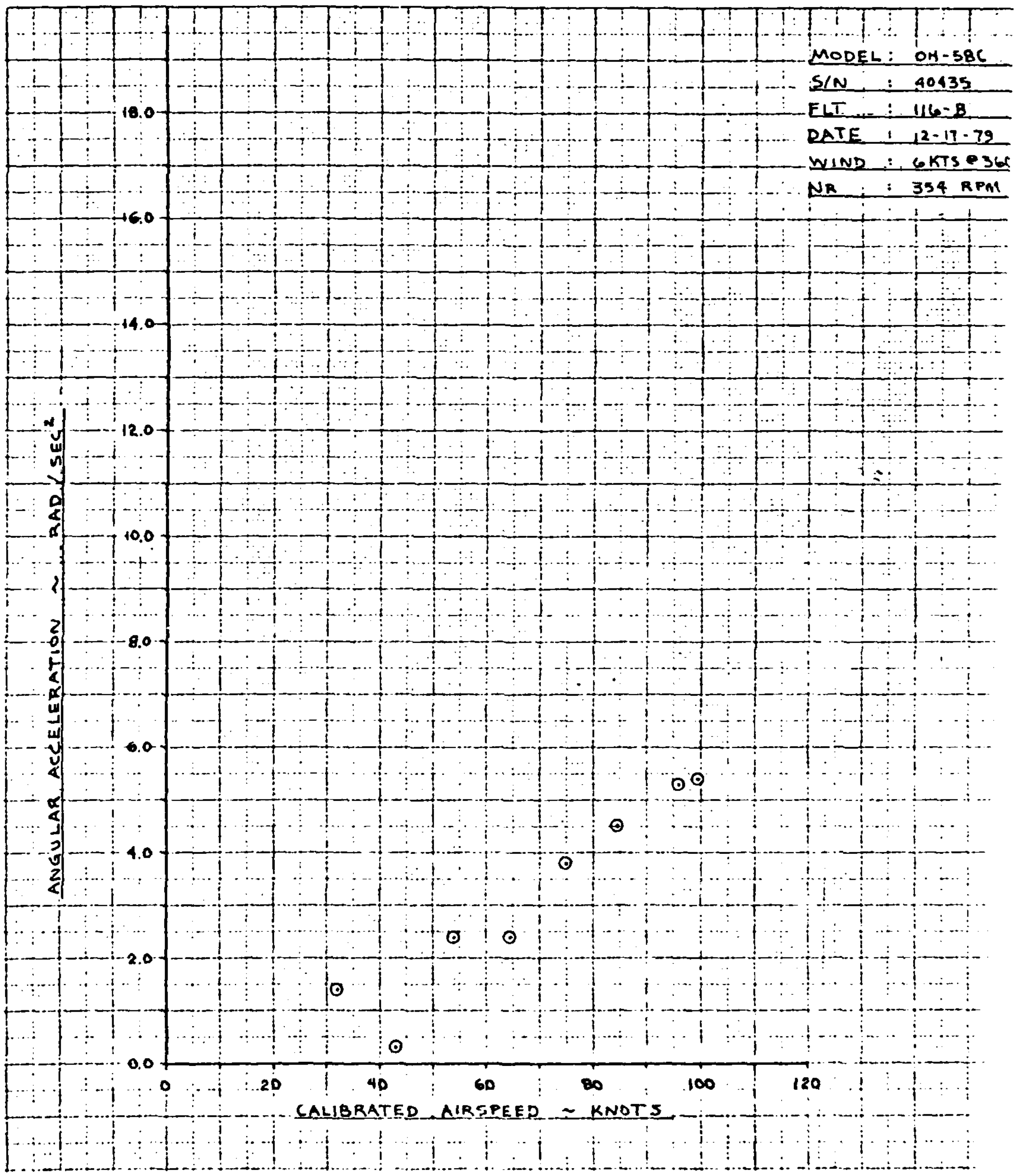

Figure A-7. Rockwell MMS line-of-sight (roll) vibration at M/R 4/rev versus airspeed.

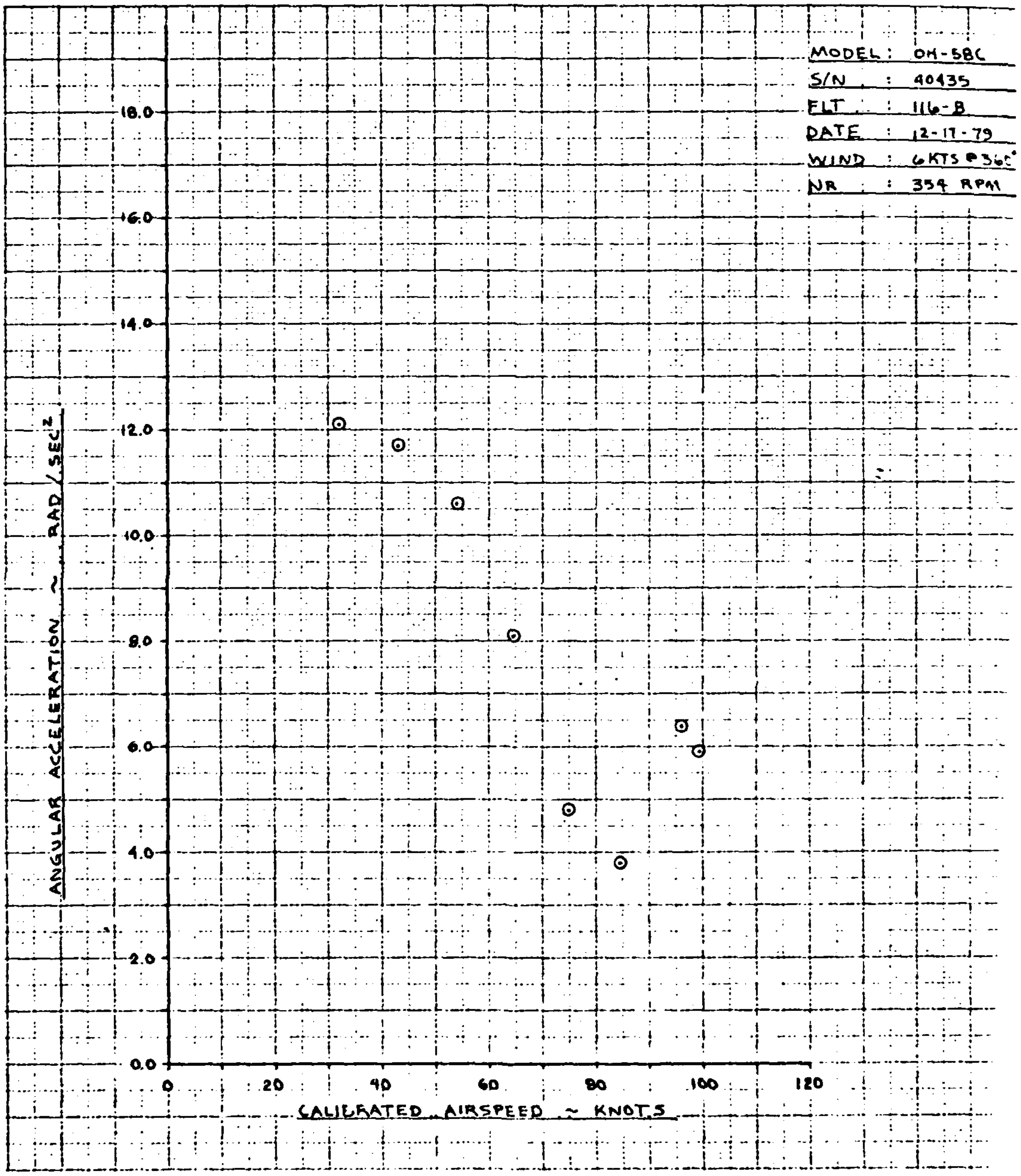

Figure A-8. Rockwell MMS line-of-sight (roll) vibration at M/R 6/rev versus airspeed.

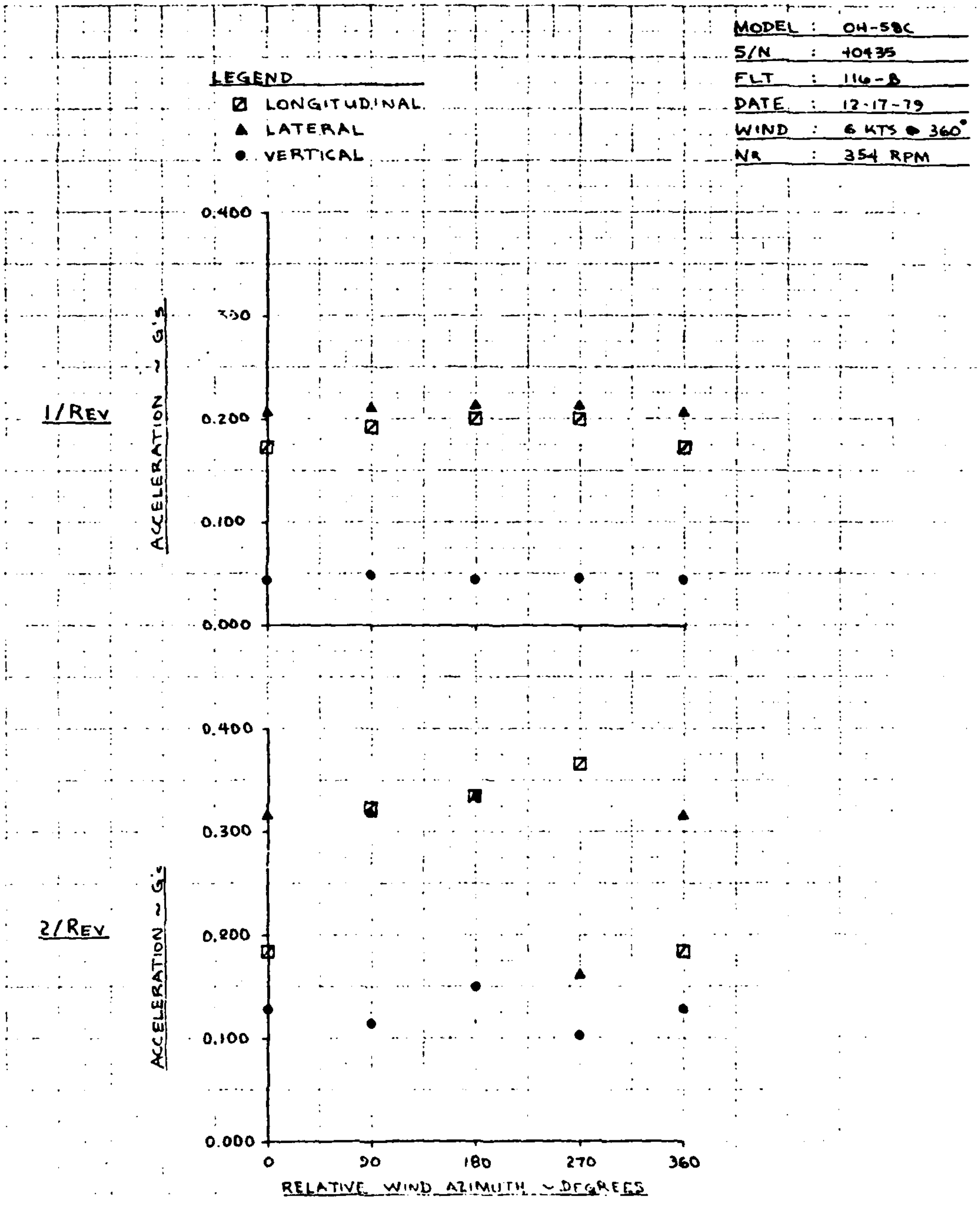

Figure A-9. Rockwell MMS trunnion (cg) vibration at M/R 1/rev and 2/rev in IGE hover.

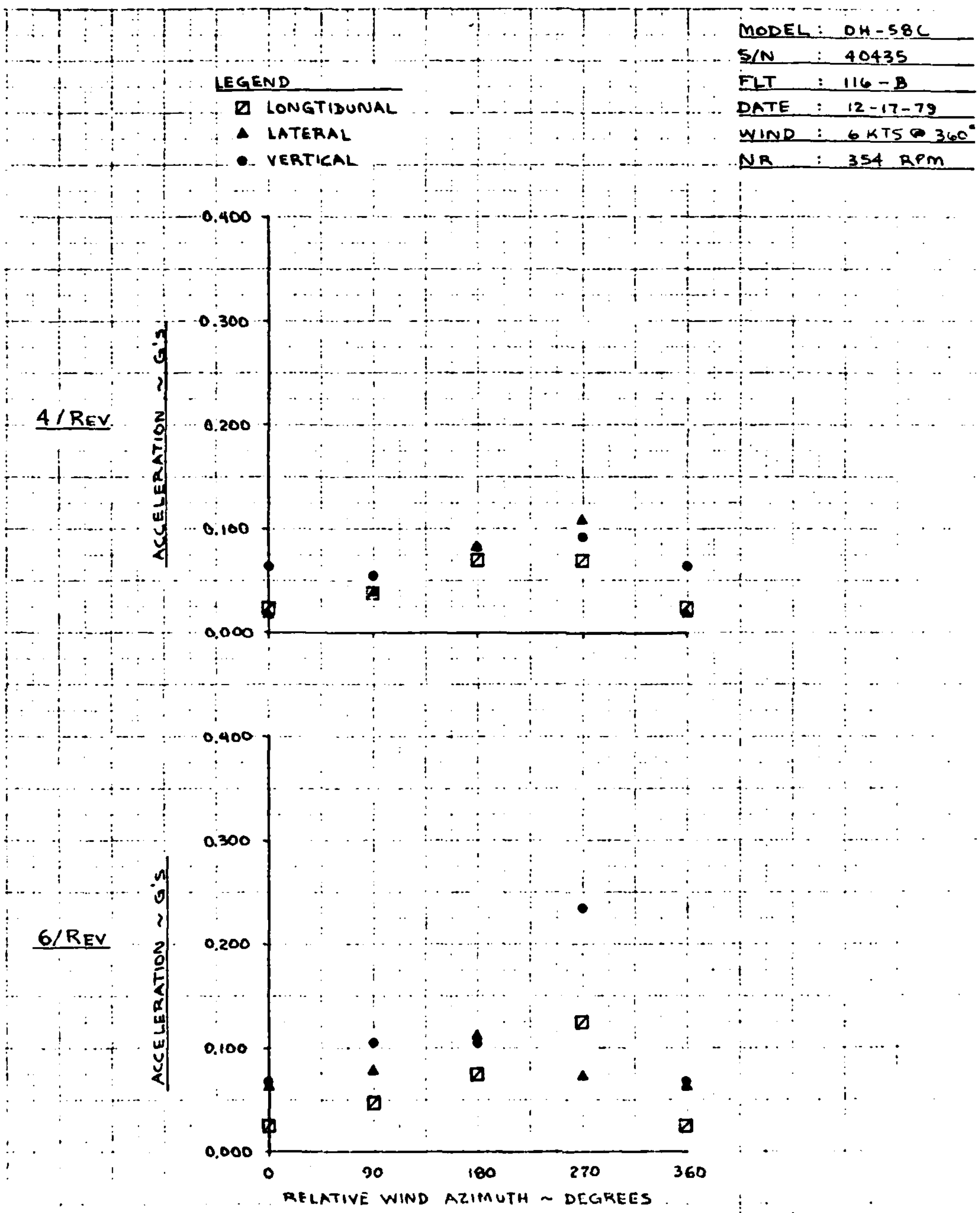

Figure A-10. Rockwell MMS trunnion (cg) vibration at M/R 4/rev and 6/rev in IGE hover.

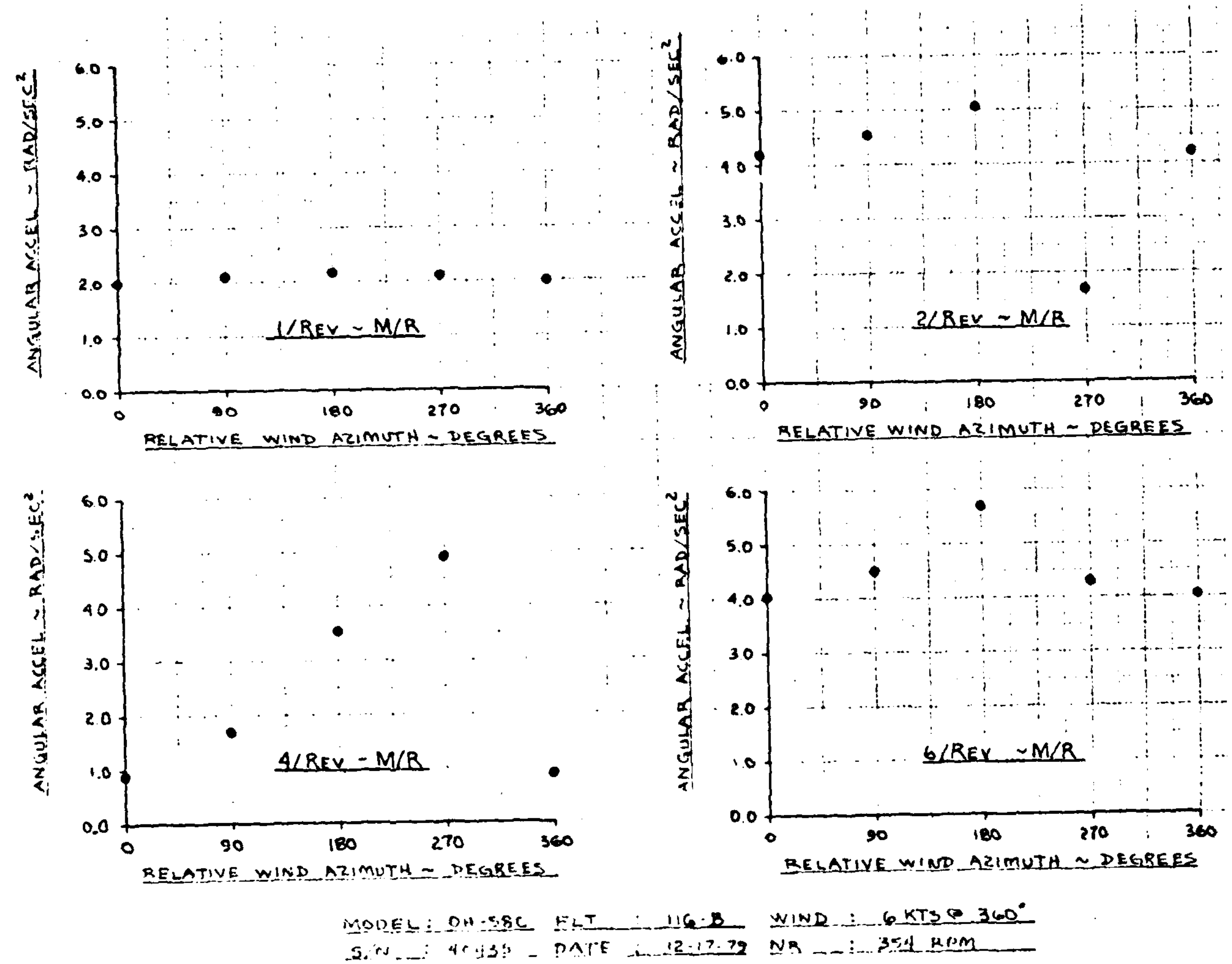

Figure A-11. Rockwell MMS line-of-sight (roll) vibration at M/R 1/rev, 2/rev, 4/rev, and 6/rev in IGE hover.

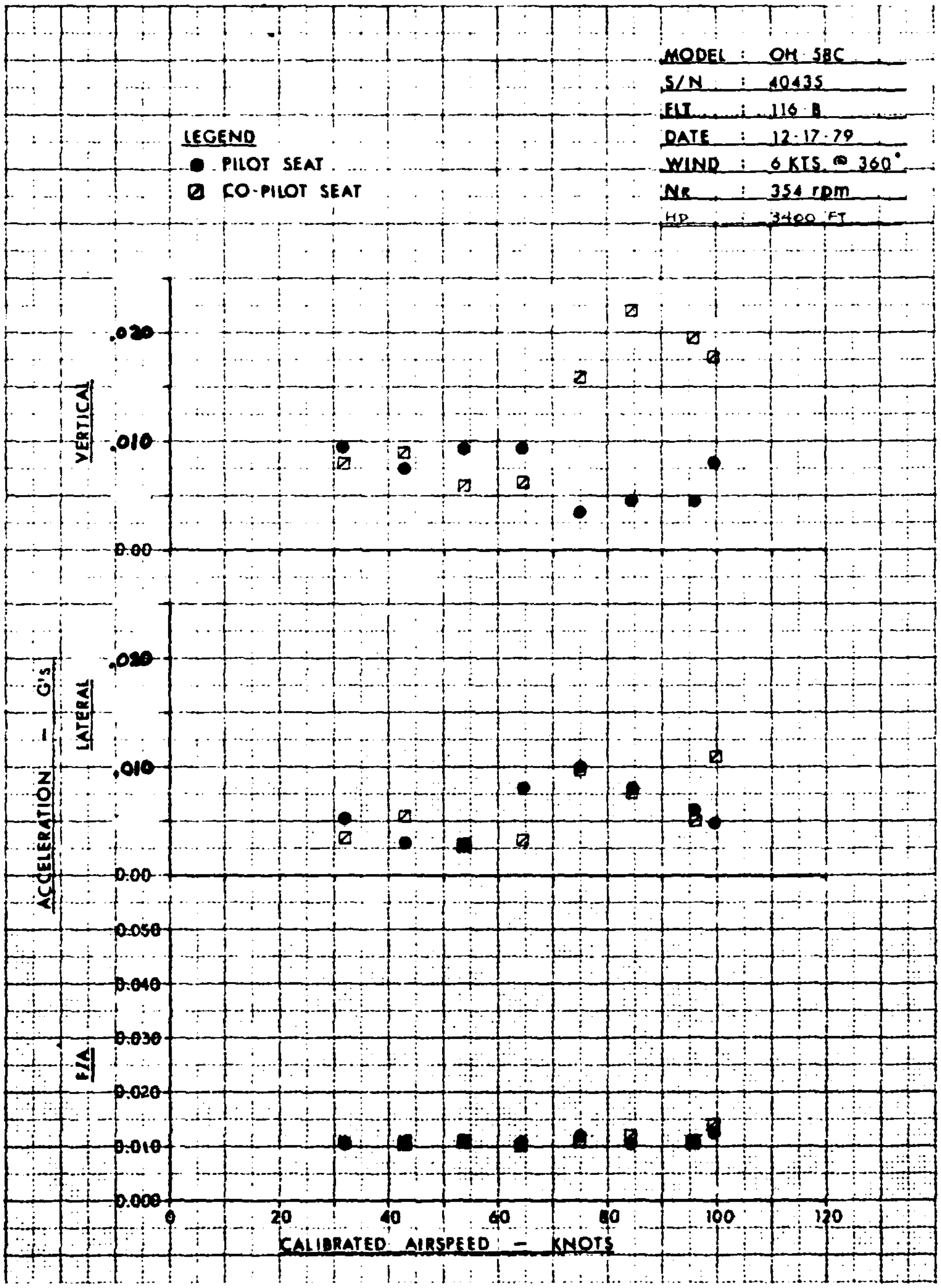

Figure A-12. Crew seat vibration at M/R 1/rev versus airspeed.

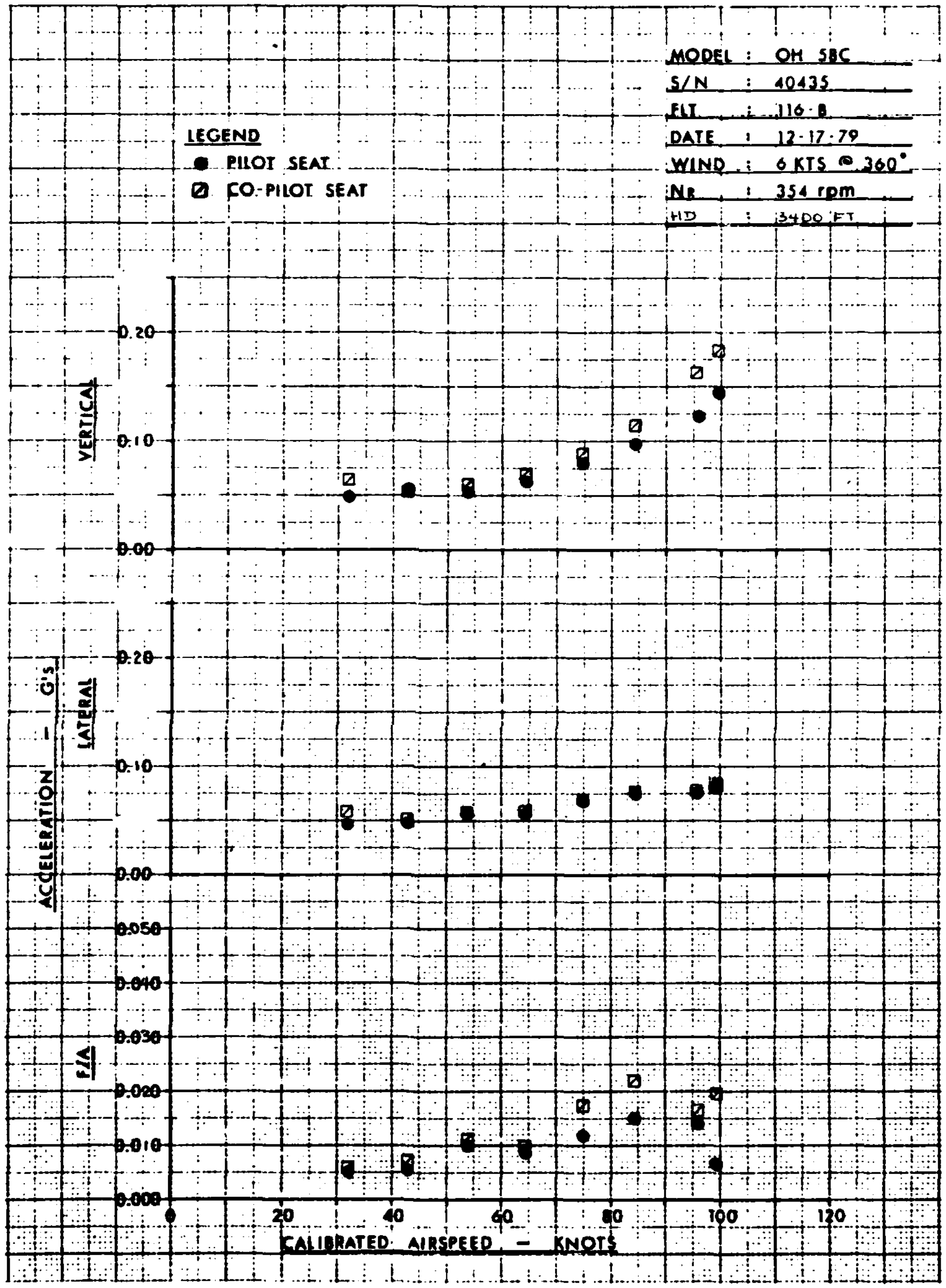

Figure A-13. Crew seat vibration at M/R 2/rev versus airspeed.

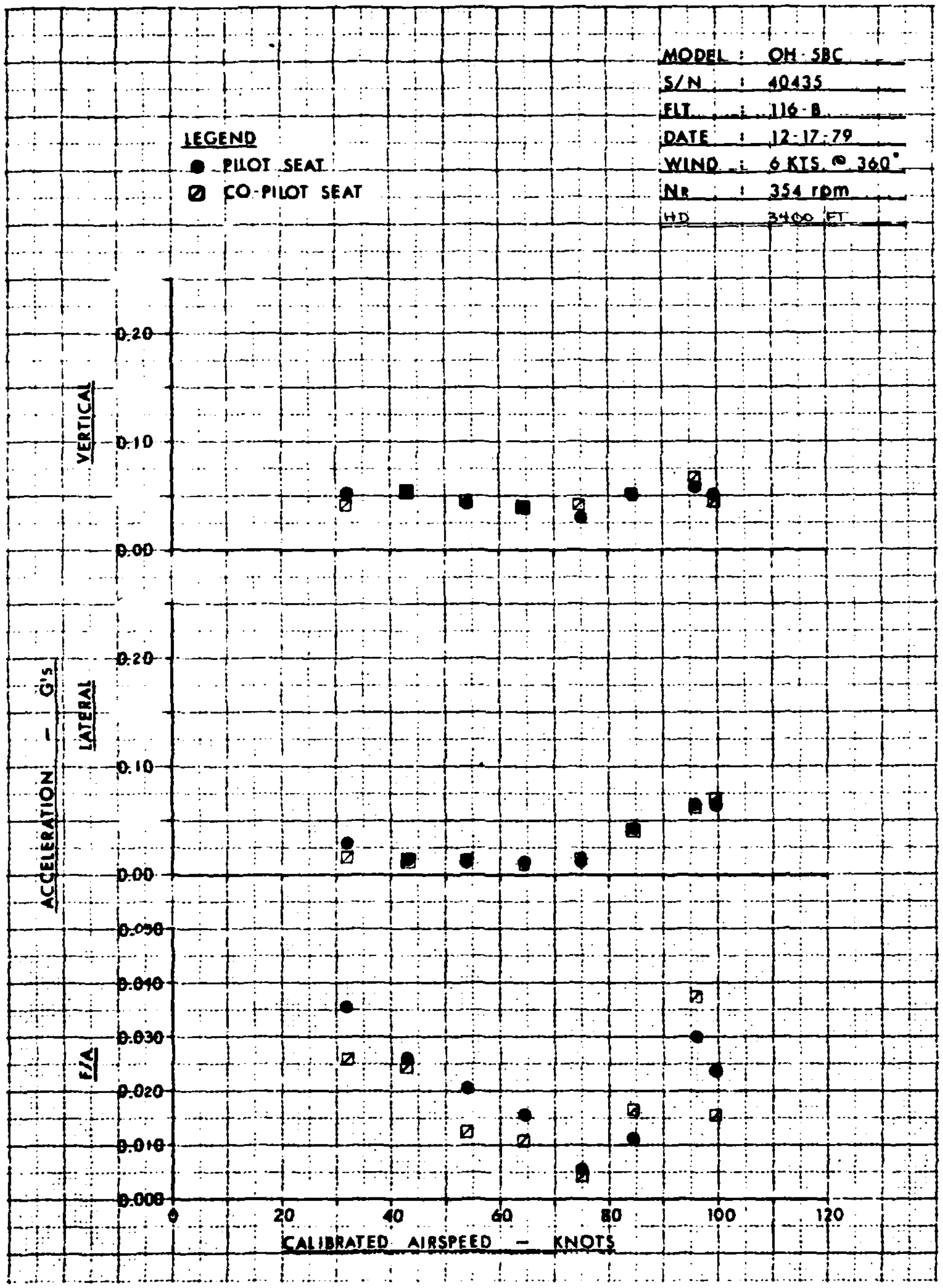

Figure A-14. Crew seat vibration at M/R 4/rev versus airspeed.

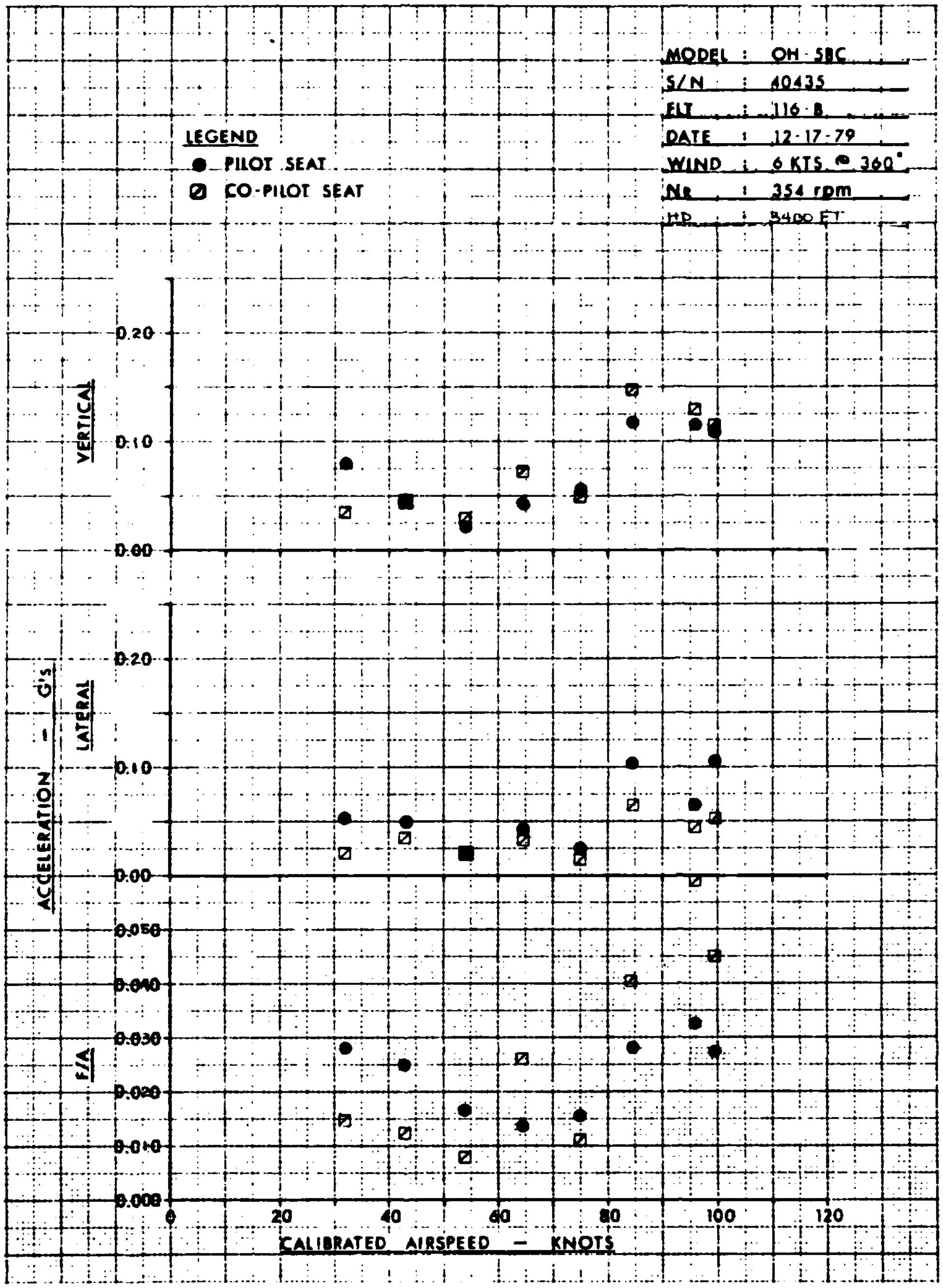

Figure A-15. Crew seat vibration at M/R 6/rev versus airspeed.

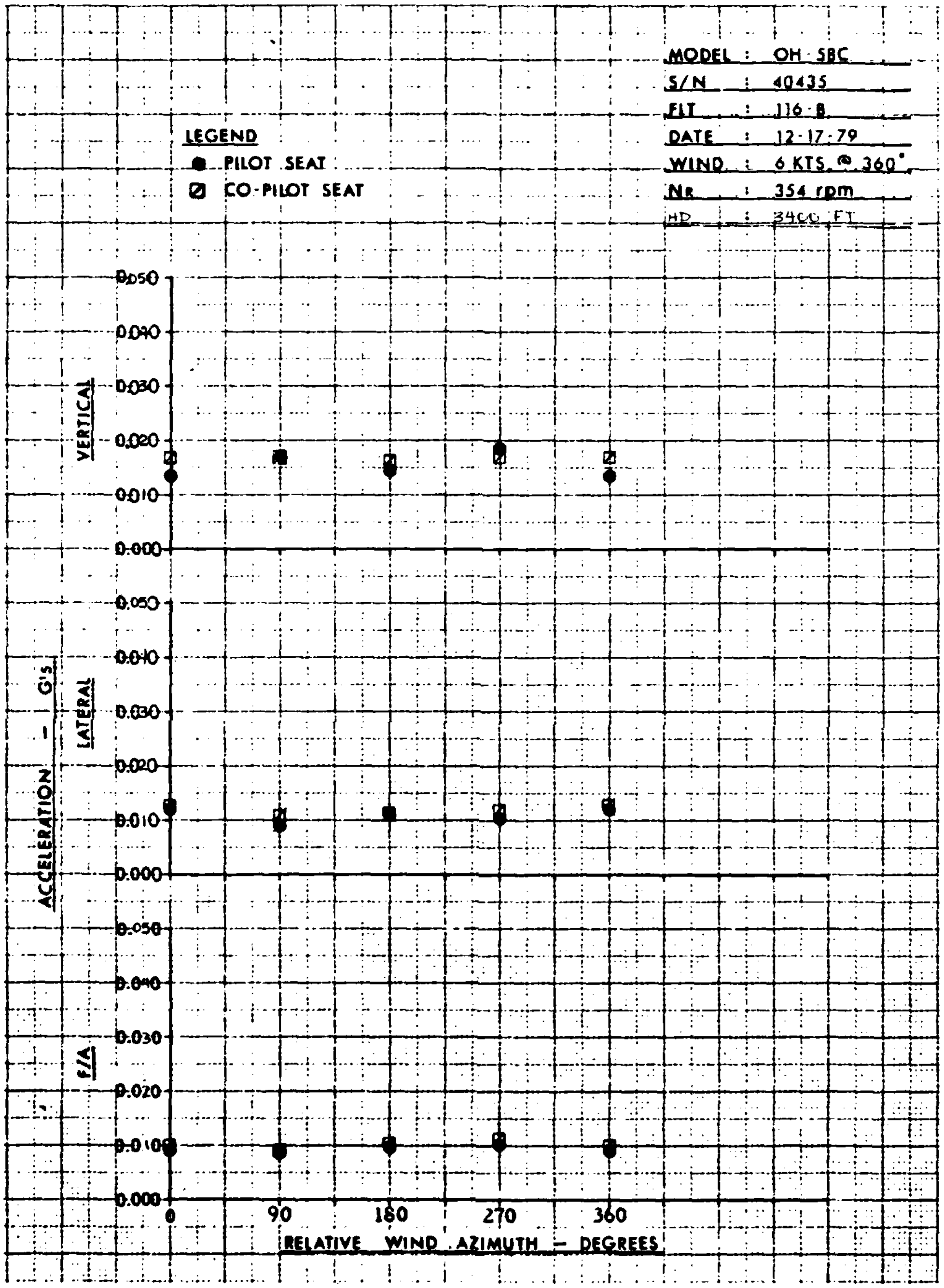

Figure A-16. Crew seat vibration at M/R 1/rev in IGE hover.

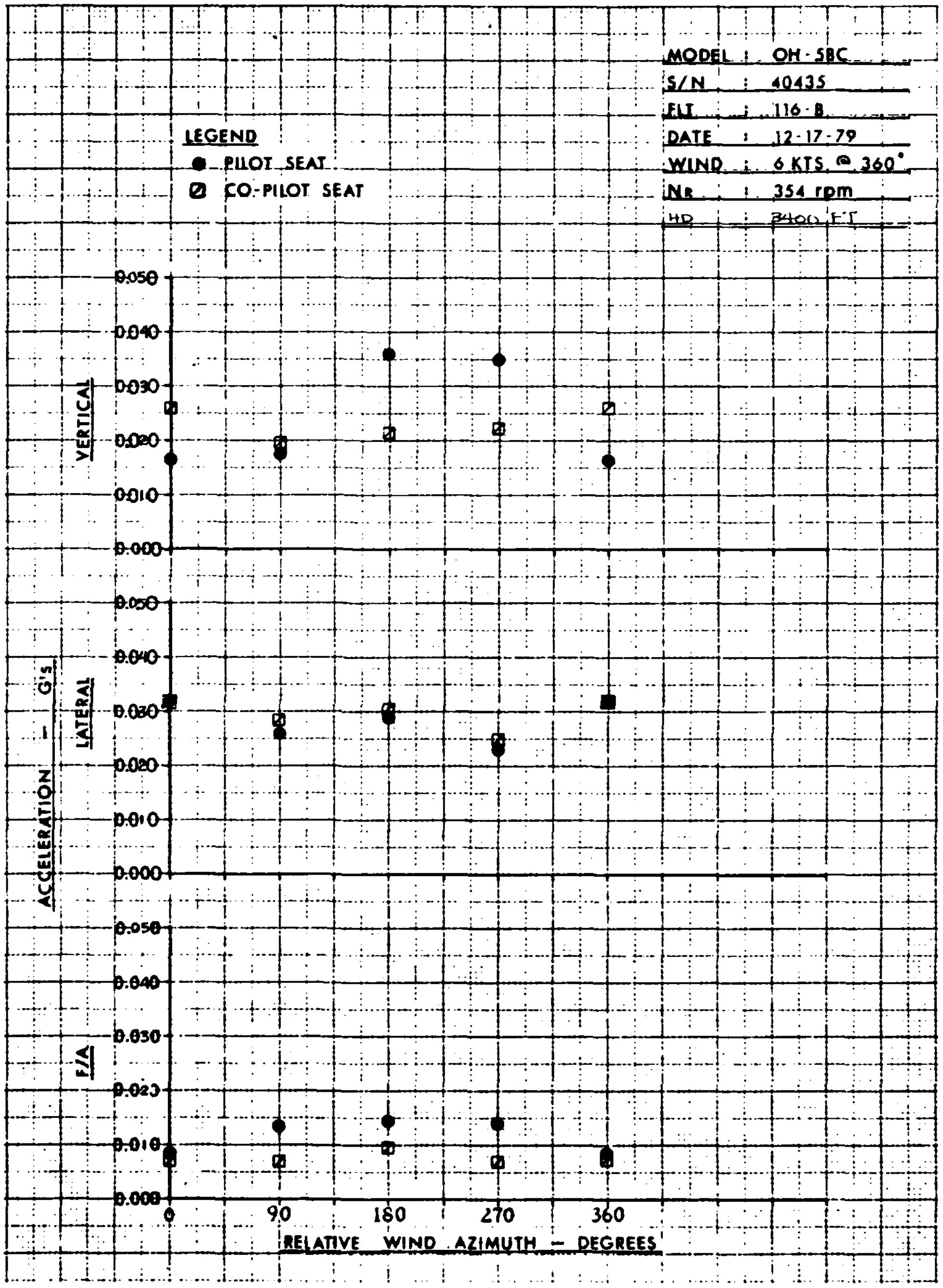

Figure A-17. Crew seat vibration at M/R 2/rev in IGE hover.

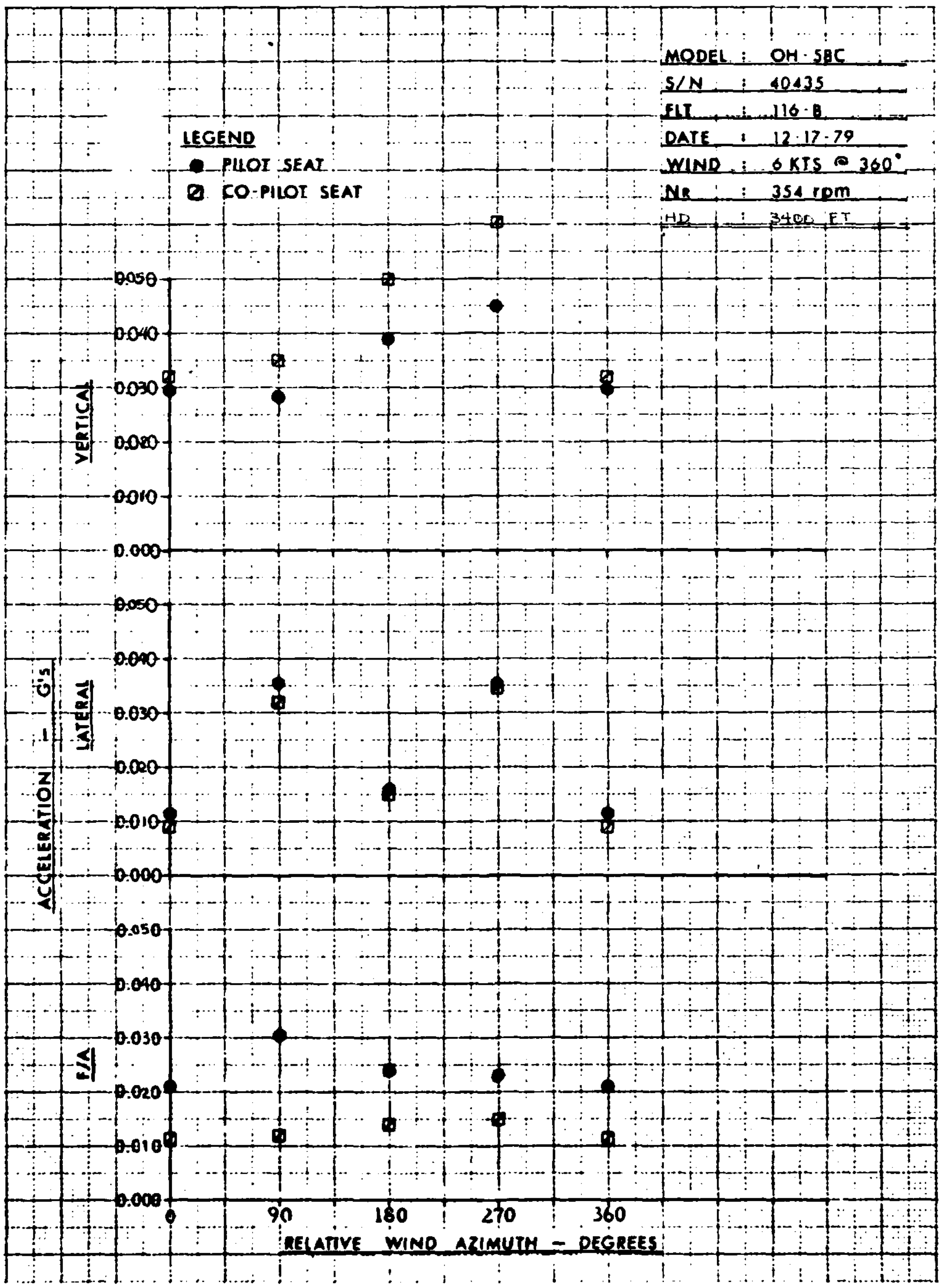

Figure A-18. Crew seat vibration at M/R 4/rev in IGE hover.

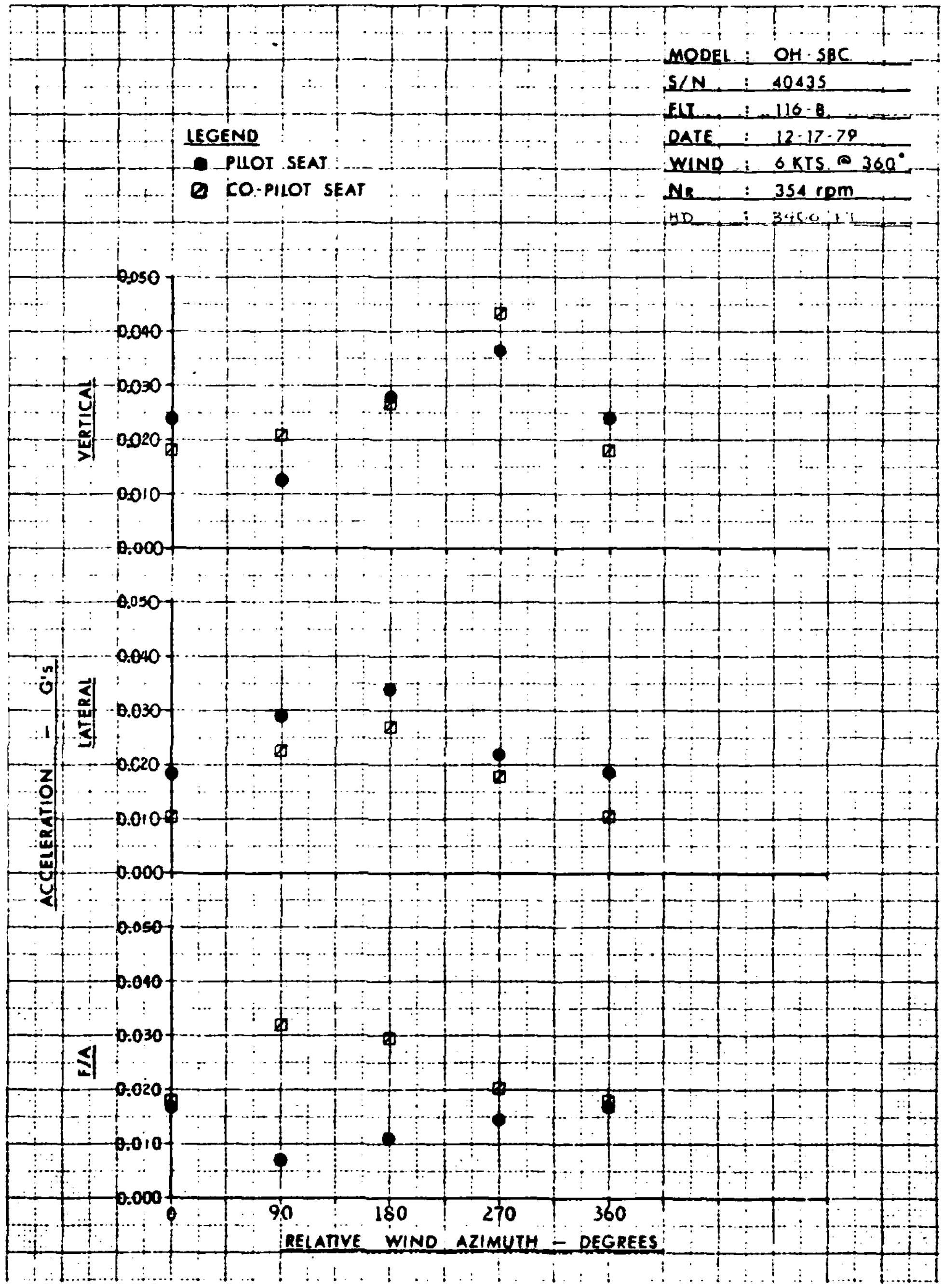

Figure A-19. Crew seat vibration at M/R 6/rev in IGE hover.

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